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GENERAL MEETING,
HELD AT THE INSTITUTE ROOMS, ST. JAMES'S CHAMBERS, SHEFFIELD,
JANUARY 30TH, 1912.

MR. M. H. HABERSHON, PAST-PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, which were confirmed.

The CHAIRMAN announced the election of the following gentlemen:—

ASSOCIATE—
Mr. WILLIAM HENRY BREALEY, 48, Basford Street, Darnall, Sheffield.
STUDENT—
Mr. BERNARD AVERY BEACH, Birran, Ackworth Moor Top, Pontefract.

DISCUSSION OF MR. THOMAS BEACH'S PAPER ON "THE SHAW HEMSWORTH OVERWINDER."*

Mr. THOMAS BEACH (Pontefract) said that it might be of interest to the members to have some account of the experience gained by the use of the Shaw Hemsworth overwinder since its description appeared in the *Transactions* and it was inspected at the

* *Trans. Inst. M. E.*, 1911, vol. xlii., page 92.

Hemsworth Collieries in August, 1911. On several occasions the gear had come into operation, and although it was difficult to say definitely what would have happened if the gear had not acted, he was fairly confident that one overwind if not more had been prevented. On one occasion the engineman had shut off steam at the usual point, and had got to within three revolutions of the top, when he found that, owing to an unusually heavy load (there being four tubs of dirt and two tubs of coal on), he could not land. More steam was thereupon admitted, which caused an increase of speed, the governor-balls to open, and the bevelled pawls to close and trip with the cone, thus closing the throttle and applying the primary dead-weight brake, which brought the engines to a stand about half a revolution before the banking-point was reached. This was a very satisfactory proof that the gear afforded, by means of the primary brake, an efficient safeguard against the descending cage being dashed on to the sump baulks; and this, it would be admitted, was a feature the value of which could not be overestimated. The ascending cage was doubly protected by the secondary or final brake. The question of varying loads presented one of the chief difficulties to be overcome in connexion with overwinders, as an extra heavily-loaded cage would cause lengthening of the rope, and thus disorganize the setting of the final brake trip-gear. It was necessary, therefore, to leave to the engineman a fair margin in that respect. At Hemsworth, the final brake was set to trip at 3 feet above the banking-level. The method of coupling up the trips to the steam-valve, etc., was a matter of some importance, and offered a subject for discussion and criticism. After careful consideration, the following scheme was adopted at Hemsworth:—

Upon the primary brake coming into operation the small equilibrium valve is opened, which allows the steam to escape from the under side of the steam-brake piston, and the dead-weight brakes to go on; though, as the brake-engine steam-supply is not cut off, but passes through the lower portion of the cylinder, it forms a cushion, and the brake goes on so gradually that no harm need be feared from undue shock. The action of closing the throttle-valve, which takes place simultaneously with the opening of the equilibrium valve, snatches the lever out of the engineman's hand, thus calling his attention to

the fact that something is wrong; but he can immediately, and before the overwinder has been reset, regain his steam by a little extra exertion, and, by reversing, can put the steam against the engine, thus assisting the primary brake to bring the engines to rest. It may here be noted that even if the primary brake did fail to act, the engineman has not lost control of his engines. In the case of the engineman fainting or dying at his post, the engines would either be brought gradually to a standstill by the primary brake, or if this did not come into operation until the last one or two revolutions of the wind, it is just possible that the engines might go on until the final brake came into operation, which would immediately bring the engines to a standstill; but before this brake came on, the speed must have been so much reduced that no shock of any serious nature would ensue, inasmuch as the primary brake practically shadows the engines for the last six or seven revolutions, and ensures gradual reduction of the speed until the stopping-place has been reached. The action of the final brake is necessarily both very quick and powerful, as, by the method of coupling up, both the throttle-valve is closed and the dead-weight brake and the full steam-brake pressure on the top side of the brake-engine cylinder are applied. This brake can only come into operation before the primary brake has been tripped in two ways:—(1) When the engines have crept very slowly through the primary brake and gone past the banking-level; or, (2) when they have been started from rest in the wrong direction. In either case speed cannot have been attained, therefore undue shock need not be feared, and it is imperative that very powerful braking pressure should be applied in this position if detaching is to be avoided. The wooden brake-paths on the Hemsworth drums have been covered with "Ferodo" brake-lagging, which gives a good grip to the iron brake-strap, and is, moreover, quite uninflammable.

When these experiments were first started and the primary brake put on, there was considerable sparking and smoke from the brake-strap, but this was overcome by using "Ferodo" lagging, which answered very well. A certain amount of smoke came from it, but this was inevitable, on account of the fat and oil splashing off the rope. The gear had been in continual operation at Hemsworth, and not the slightest trouble had been experienced with it.

Mr. M. H. Habershon (Sheffield) thanked Mr. Beach for his further remarks on the overwinder, and referred to the discussion which took place when the subject of overwinding was introduced at the meeting of the members of The Institution of Mining Engineers in London in June, 1911, when reference was made by several speakers to the question of the brake power in regard to the strength of the drum. Mr. Habershon pointed out that the new Mines Act would require, in cases where pits are over 300 feet deep, that there shall be some automatic contrivance for the prevention of overwinding, but the choice of apparatus would be rather difficult, because in many cases drums were not constructed to withstand the sudden application of very powerful brakes. Mr. Beach had called attention to this point himself in reading his paper at Hemsworth. The Home Office had prescribed that certain things should be done without sometimes considering the existing conditions, but the matter was really a serious one, and he (Mr. Habershon) invited further questions before the discussion was closed.

DISCUSSION OF MR. ALAN E. L. CHORLTON'S PAPER ON "METHODS OF DRIVING BY GAS-ENGINES FOR COLLIERIES."*

Mr. A. E. L. Chorlton (Manchester), referring to the questions asked by Mr. Habershon and Mr. Rhodes in the discussion which took place at the last meeting, relating particularly to the amount of ash that could be burnt in the waste-fuel, said that there was a representative of the Power Gas Corporation present who would probably explain that fuel containing as much as 60 per cent. of ash could be utilized.

Mr. Habershon had raised one point in regard to the amount of water used for gas-engines as compared with steam-turbines. In the paper this was stated to be in the proportion of 6 to 1 for an ordinary turbine. In the case of the exhaust-steam turbine (which was a great favourite, because it was cheap, as it allowed of the utilization of much out-of-date plant), the ratio was even greater. If the consumption of the exhaust-steam turbine was 30 pounds of steam, and water was used at a fairly high temperature,

* *Trans. Inst. M. E.*, 1911, vol. xlii., page 315.

possibly 70° Fahr., fully 40 pounds of water per pound of steam would be required for surface condensing. Thus, the exhaust-steam turbine used twelve times as much water as the gas-engine. This statement might be modified by the fact that a cooling system might be in use, in which case the loss was only by evaporation.

He had hoped in the discussion at the last meeting that something would be said in regard to the gas-driven winding-engine. He admitted that it was a very difficult problem, but at the same time he thought that it was a very taking proposition, and as the project could only go forward by keen criticism, he had included it in his paper with a view to the promotion of discussion. Since the reading of his paper there had appeared in the press several articles referring to it and connecting therewith the closed-circuit air system. Mr. Dunlop, of Glasgow, had shown that the economy was great in some instances, and, in the case of winding where the winding-engine was adjacent to the gas-engine, that the efficiency was greater than with electric winding, and the first-cost less; but he had not dealt with the use of the closed-circuit system for mining circumstances. The figures mentioned in his (the speaker's) paper in regard to coke-ovens had been criticized as being too favourable, but he could not amend them.

Mr. Ash Hollis (Stockton-on-Tees) explained that it was only within the last few years that attention had been called to the utilization of low-grade fuels. Bulk trials had been carried out, on an experimental plant, with washery refuse, belt-pickings, bye-product coke-oven breeze, etc., with fuels containing up to 60 per cent. of ash, and although it had been found possible to gasify fuels containing 60 per cent. of ash, the results obtained with such high ash-content had not proved altogether satisfactory. A gas perfectly suitable for engine-driving or heating purposes had been generated from fuels containing from 44 to 50 per cent. of ash; about 70 pounds of sulphate of ammonia had been obtained from the gasification of 1 ton of bye-product coke-oven breeze, and as much as 78 pounds per ton from a mixture of colliery waste and coke-breeze, the gas produced having a calorific value of 130 British thermal units. At the Birchenwood Collieries there was a plant gasifying 320 tons of colliery waste and coke-breeze per day, the gas being used for firing boilers and gas-engine driving. The Power Gas Corporation had also put

down plants for gasifying coke-oven breeze; the gas from this was used for burning bricks in Hoffman continuous kilns. The gas from the breeze had a calorific value of from 125 to 130 British thermal units.

Mr. Thomas Beach (Pontefract) asked Mr. Hollis whether he felt that the use of fuel containing as much as 50 to 60 per cent. of ash was an economical practice, as there was bound to be a tremendous amount of refuse. He was rather astonished to hear that good results could be obtained from anything having so high a percentage of waste.

Mr. Hollis replied that the ash was removed mechanically from the producer, and that two men only were required to deal with the ash from 320 tons of coal per day. Whether low-grade fuels could be dealt with economically in bye-product gas-plant was entirely a question as to the percentage of nitrogen in the fuel and the amount of sulphate that could be recovered. Where low-grade fuels could be delivered to gas-producer plants for practically handling charges only, and from 70 to 80 pounds of sulphate of ammonia per ton of fuel recovered per ton of fuel gasified, a gas-plant proved a very paying proposition.

Mr. H. W. Ravenshaw (London) referred to the working of gas-engines, in which direction he had had considerable experience. He had used all kinds of gas, and had generally found that to ensure good working there should be as little marsh-gas and hydrogen as possible, and in order to get a good running engine there should be a very large proportion of carbon monoxide present. In his (Mr. Ravenshaw's) experience it was a regular thing with the Mond plant to obtain from 80 to 90 pounds of sulphate per ton of good coal. With regard to the working of gas-engines, he was of the opinion that when mining engineers came to adopt them they would also have to adopt special treatment. Steam-engines, although uneconomical, ran well with very little attention, but gas-engines required rather more special attention. The valves and pistons in particular must be kept in good working order. With some engines a very good consumption was obtained up to about 80 per cent. of the full load. The makers of the engines would guarantee good consumption up to full load, but it was at that point that

the trouble occurred. If the consumption were taken, it was found that this climbed up per kilowatt-hour or brake-horse-power-hour enormously on the last 10 per cent., and when one tried to get an overload, there was a difficulty. The reason for this was that the wear in the cylinder was much greater at the back than at the front. On the back rings there was a good deal more wear, and he had had experience with engines which wore $\frac{1}{32}$ of an inch in 6 months: this appeared to be due to the high pressure on the back rings, making a very high ring-pressure on the cylinders. He proposed the use of floating rings, which should not be a tight but rather a fairly accurate fit in the cylinder; this he believed was the practice in torpedo-boats.

Mr. M. H. Habershon (Sheffield) said that the question of the adoption of automatic controllers to prevent overwinding was connected with the general question of winding-engines, and he thought that it might be possible for Mr. Chorlton to work out some idea of putting a compressed-air cylinder on the winding-engine in some way which would lend itself to the more easy control of the speed of winding, as the work required of a controller on a winding-engine was to control the speed at any point of the wind. The question was one which electrical engineers might like to discuss, because it seemed probable that the ideal control of the speed of winding could be more easily secured with electric than with steam winding.

DISCUSSION OF MR. ERNEST BURY'S PAPER ON "THE OTTO-HILGENSTOCK DIRECT-RECOVERY PROCESS AND ITS APPLICATION."*

Mr. Wynter Blyth (Thorncliffe) said that there were one or two points which struck him on reading Mr. Bury's paper. The first was, that if coal containing a large amount of chloride were used, it was stated that the ammonium chloride would separate out in the pipes before reaching the saturator. He (Mr. Blyth) thought that the ammonium chloride would be carried into the saturator and there form some free hydrochloric acid, and it was a question whether the wear on the lead of the saturator

* *Trans. Inst. M. E.*, 1911, vol. xli., page 531; and vol. xlii., pages 351 and 556.

would not be very serious from the action of the hydrochloric and sulphuric acids. Another point which Mr. Blyth raised in regard to the direct-recovery process was that such process was said to be accomplished without effluent. But all processes seemed to have effluents, and he noticed in this particular paper that it was stated that, in order to recover benzol, a large amount of cooling-water would be necessary, and an effluent was obtained which was said to be much better than the ordinary ammonia effluent. It did not matter much what it was like: the chief consideration was whether the Rivers Board would allow it to pass into their streams without treatment. He would like to have some further information as to what the liquor was like, whether any samples had been fully analysed, and whether it was considered fit to be turned direct into the rivers. With regard to the question of the cooling of gas for the recovery of benzol, he did not really see why it should not be cooled before it went into the saturator, as in the Koppers process, instead of afterwards, as in the Otto-Hilgenstock process. It seemed to him that the treatment of the small amount of liquor with lime, as in the Koppers process, would minimize the decaying of the saturator by preventing the formation of hydrochloric acid, and the effluent, being small in quantity, would not be any more difficult to get rid of than in the Otto-Hilgenstock process, providing that the effluent from the latter process could not be directly turned into a river.

Mr. M. H. Habershon (Sheffield) said that although Mr. Bury was not present, he would have an opportunity of replying to the discussion later. He (Mr. Habershon) understood Mr. Bury to say at Leeds that benzol was being recovered at one installation, and, if that was the case, he would be glad to know what quantity of benzol was obtained per ton of coal carbonized.

THE SOUTH STAFFORDSHIRE AND WARWICKSHIRE INSTITUTE OF MINING ENGINEERS.

GENERAL MEETING,

HELD AT THE UNIVERSITY, BIRMINGHAM, FEBRUARY 19TH, 1912.

MR. J. C. FORREST, PRESIDENT, IN THE CHAIR.

The minutes of the last Council and General Meetings were read and confirmed.

Replies from Mr. H. Martin, Mr. A. Sopwith, and Mr. S. F. Sopwith to the votes of condolence passed at the last meeting were read by Mr. Alexander Smith in the absence of the Secretary.

GEOLOGICAL SURVEY.

MR. ALEXANDER SMITH (Birmingham) read the following reply from the Director of the Geological Survey to the resolution that had been forwarded to him after the last meeting*:—

"I beg to acknowledge the receipt of your letter containing the resolution passed by the South Staffordshire and Warwickshire Institute of Mining Engineers on the 18th ultimo."

"In reply, I have to point out that the work on which the Geological Survey is now engaged is the primary 6-inch survey, and is not merely a revision of the old 1-inch maps. It is impossible, therefore, to avoid going over the worked-out areas."

"The general plan on which we are working involves the survey of the area between the South Staffordshire and Warwickshire coal-fields, and also of the area lying to the west of the South Staffordshire coal-fields."

"With regard to the first-mentioned area, the surveying of the ground covered by the New Series Sheet 154 is almost completed, and the publishing of that map will be proceeded with as soon as possible. Sheets 168 and 169 take in the remainder of the area between the Warwickshire and South Staffordshire coal-fields, and are included in the field-work which has already been arranged for 1912."

"As regards the ground lying west of the South Staffordshire coal-field, while fully recognizing the importance of examining it as soon as possible, I regret that we could not undertake it this year without breaking the continuity of the survey upon which we are engaged."

"I take this opportunity of expressing to the members of your Institute the thanks of the Geological Survey for the assistance which they have rendered to us."

(Signed) J. J. H. TEALL, *Director*

* *Trans. Inst. M. E.*, 1911, vol. xlii., page 389.

MINES RESCUE COMMITTEE.

Mr. ALEXANDER SMITH (Birmingham) said that, as Hon. Secretary of the South Midland Coal-owners Mines-rescue Committee, which was appointed at the instigation of the Institute, he would like to add to the report* which he had given of the proceedings of this committee at the last meeting that it had now been arranged to establish the Instruction Centre in connexion with the Mining Department of the Birmingham University and under the direction of Prof. Cadman.

The coal-owners had undertaken to indemnify the University against the cost, and a sub-committee was now engaged in considering the applications for the position of Instructor. The work of this Instructor would consist of training Instructors for the different stations or collieries, visiting the several districts and assisting in establishing stations, and testing and inspecting apparatus, which would be uniform for the South Midland area, comprising South Staffordshire, Cannock Chase, Warwickshire, South Derbyshire and Leicestershire, and Shropshire.

The following gentlemen, having been approved by the Council, were elected:—

MEMBERS—

Mr. J. ANDREW, Park Bean, St. Ives, Cornwall.
Mr. M. J. FOGGO, The Cottage, Chasetown, Walsall.
Mr. J. W. MCTRUSTY, Earl's Road, Nuneaton.

ASSOCIATE—

Mr. E. B. DAVENPORT, Minas de Santo Domingo, Mertola, South Portugal.

STUDENTS—

Mr. C. BINDING, 61, Lawrence Hill, Bristol.
Mr. S. G. ROPP, 28, Bournbrook Road, Birmingham.
Mr. R. H. SMITH, 8, Bournbrook Road, Birmingham.
Mr. V. L. D. UZIELLI, Arden Grove, Dorridge, Warwickshire.

The PRESIDENT (Mr. J. C. Forrest) feelingly referred to the absence of the Secretary (Mr. G. Douglas Smith), who, he said, had been ordered abroad on account of his health. He was sure that Mr. Smith had the sympathy of the members, and they all hoped that he would soon return much benefited by the change.

Mr. ISAAC MEACHEM read the following "Notes on the Loss of Mineral Areas in South Staffordshire":—

* *Trans. Inst. M. E.*, 1911, vol. xlii., page 388.

NOTES ON THE LOSS OF MINERAL AREAS IN SOUTH STAFFORDSHIRE.

By ISAAC MEACHEM.

The question of our national coal-supply has for some years been a matter of deep interest. Its exhaustion appears to be so rapid, that to some extent a feeling of alarm has been raised. The Royal Commission on Coal Supplies has held its sittings, taken evidence, and made its report. This report is most valuable, containing as it does much information of deep interest to all concerned in mining. The collation of statistics showing our probable future resources in mineral wealth has given us some rough idea of the duration of the mining industry.

One part of the work of the Commission has been to enquire into the question of waste in working, loss of coal in barriers, and support to buildings and other properties. In connexion with this question of waste, there is, in the writer's opinion, one feature, relating more especially to the loss of coal left as support to the surface, which has not received the attention that it deserves, and was but lightly touched upon by the Commission; yet it concerns the South Staffordshire district to a serious extent. It may, and in fact does, concern other districts, but, so far as the writer knows, not so acutely as this district. Being intimately connected and familiar with the South Staffordshire coal-field, the writer will confine his remarks to what he knows from personal experience.

Paradoxical as it may seem, it is a fact that in this district the mineral area will soon be exhausted despite the non-exhaustion of our mineral wealth, and this is mainly due to the large areas left unworked owing to (1) submergence, and (2) to support left for the surface.

The inhabitants of this Kingdom are repeatedly reminded that its mineral treasures are an important national asset; in fact, mineral wealth is national wealth. For some years mining engineers in South Staffordshire have been rather despondently

watching the gradual exhaustion of the mineral wealth of the district; and the slow but sure removal of the cognate industries to other districts involves an incalculable loss to the Midlands. Every cubic foot of coal, ironstone, or fire-clay left in the earth is therefore so much wealth lost, and lost irretrievably.

In the writer's early days, he was engaged for several months as assistant to a body of mining engineers who devoted much time and work to formulating a scheme for the unwatering of mines in the South Staffordshire district, and the keeping of them unwatered. In this district the mineral outcrops are unusually extensive in proportion to the area. Early mining operations were all in the shallow mines round these outcrops, so that a large proportion of the area of this coal-field is broken ground, ready to receive the rain from heaven and pass it into the mines.

The above-mentioned scheme developed. An Act of Parliament was secured, namely, "The South Staffordshire Mines-drainage Act." Under the ægis of this Act the scheme has now for some years been worked by a Board of Commissioners with the guidance of a capable engineer. The Commissioners, however, have been but partly successful in their task; and it would appear that under present conditions many million tons of valuable minerals will be irretrievably lost, unless another scheme, more far-reaching and powerful than the present one, is formulated and adopted. The writer does not think that he is greatly mistaken in saying that there are now upwards of 40,000,000 tons of coal and ironstone in the earth which will be utterly lost unless some scheme is devised and set to work to rescue them. The loss of this mineral wealth is a serious matter, and what it means to the district cannot be adequately realized. Not only so, but ominous signs may be seen that the output of minerals in this district will in the near future be so reduced that the income therefrom in the way of mine-drainage rates will be insufficient to pay the working-expenses of the necessary machinery with which to keep the Commission going.

There is also the loss of minerals which are being left for the support of buildings and surface-works. A problem which the mining engineer is frequently called on to solve is the area of mine that must be left for the support of buildings on the surface. Despite all the care taken to protect the buildings from

damage, damage is often alleged; and the mine-owner is compelled either to pay extortionate compensation, or to fight out his case in the law-courts. In the end he is often heavily mulcted in damages and costs, and in either case compelled to leave large areas of his mine to support the property, the mine representing in most cases many times the value of the property which has to be supported. It may be asked: Why does not the mine-owner in such a case purchase the surface property, and thus save himself the loss of the mine and risk of lawsuits? First, in speaking of the value of the mine, it must be recognized that the owner's profit in working the mine represents but a small part of its value, for coal, ironstone, and fire-clay mining has a value not only for the mine-owner, but for the workmen, the parish, the district, and, in fact, for the nation at large. Second, as soon as it is known that a mine-owner wishes to purchase, the value of the property concerned is run up, and exorbitant prices are demanded. Again, the writer's experience in these matters is that not only does the value of the property rise, but oftimes search is made for any sign of fracture in the building—and in what building cannot fractures be found?—and when such are found, the unfortunate mine-owner is pounced on for damages. This is no mere imaginative statement, as the writer has known many such cases. Some years ago he endeavoured on behalf of a mine-owner to purchase some property. The property instantly went up in value, and the writer declined to purchase. Then dilapidations were discovered; and three actions for compensation were brought. Fortunately, the property-owners were not able to substantiate their claims, but the anxiety and loss in defending the actions was very considerable to the mine-owner, and he abandoned a considerable area of mine so as to ensure himself against the risk of further trouble and loss.

The question of right of support is a serious one, as comparatively small properties require a considerable area of mine for support, the area increasing with the depth of the mine. Prof. William Galloway, in his evidence before the Royal Commission on Coal Supplies, stated that "The rule fairly generally followed is to make the diameter of a round pillar, say, equal to the depth from the surface at which the seam lies, and of course the same thing would hold good for square pillars, or for a one-sided support; that is to say, a one-sided support taking a line

vertically under the point to be supported, the width would be half the depth from the surface." (Other witnesses said one-third to one-half of the depth from the surface.) Think what this means! To support a property of 5 acres in area requires, at a depth of 750 feet, nearly 31½ acres of mine; and if there are but three seams of coal, each, say, 4 feet thick, the amount of coal lost would be 567,000 tons. These are facts which demand the thoughtful attention of everyone engaged in mining.

The recent judicial decision in the case of the London & North-Western Railway Company *v.* The Howley Park Coal & Cannel Company, in which it was laid down that the railway company—and as a natural result canals also—are entitled to lateral support outside the prescribed limit of 40 yards, has added to the difficulty of the working of mines, as all are aware who are concerned in the working of mines near to railways or canals. This decision will also have the effect of forcing mine-owners to leave valuable minerals in the earth, in order to avoid litigation.

Some time ago the writer was called on to give evidence at an enquiry into the mineral resources of a parish, and carefully worked out his estimates, allowing (as was thought) a sufficient margin for property support. Since then there has been litigation in that parish with respect to property support, with the result that, on looking over his estimates, the writer finds them reduced to an alarming extent, owing to the fact that an area of mine is left round the property of a radius equal to the depth of the mine, or double the distance of Prof. Galloway's liberal estimate of what should be left, and nearly three times what has been hitherto considered a safe margin. Of course, every person whose property is damaged by mining operations has a right to compensation, according to the amount of damage sustained; and with this the writer has no quarrel. But it is the enormous loss of the national wealth about which he is concerned, this loss being out of all proportion to the value of the property that has to be protected.

The question now is: Can anything be done to lessen or stay this enormous loss of mineral, both in the areas lost in support of the surface and in respect of the areas submerged by water?

The writer has already stated that the owner's profit represents but a small part of the value of the mineral worked, and that

the workman, the parish, and the community at large have a great interest in the mineral wealth. This principle is held by Prof. Galloway, who, in his evidence before the aforesaid Royal Commission, said: "I should take it that the coal is really the property of the community generally."

The value of minerals is not to be gauged by the mine-owner's profits—he only shares with many others the benefits of the minerals worked. The value of the mineral is what it realizes in the market, which value is shared in by the coal-merchant, the many trades and industries connected therewith—timber merchants, rope manufacturers, ironworks, engineers, the parish or district by its rates, and the country generally. The workmen also have a direct share in that value; all these realize their share of the mineral value; and all bear a proportionate share of the loss when mineral is left in the earth unworked. Such being the case, it is manifestly a mistake to imagine that because a mine does not pay the mine-owner to work it, it is of no value; in fact, the mine-owner's profit is but a small portion of its actual value. Therefore, the greatest loss of value of minerals left in the earth falls on the workers in the mine and the community at large.

The question now arises: If the major portion of the value of the coal, or minerals generally, belong to the community, can the community generally, through their County Councils, or through Imperial Parliament, step in and ensure that the loss shall be at least minimized? Mr. F. G. Meachem, in giving evidence before the Royal Commission on Coal Supplies, was asked the following question:—"Have you any suggestion to offer as to the best mode of ensuring the prevention of such waste and loss of fuel?" He replied: "Yes; coal above, say, 18 inches thick ought to be turned over, and if it does not pay, the landlord should help; if not, and the nation is to suffer for loss of such coal, then subsidize to so much a ton (I know this is not practical)." Although this question and answer does not refer to loss of mineral such as that alluded to by the writer, yet the principle involved is the same. The witness saw that the nation suffered through minerals not being worked, and that something in the nature of financial assistance should be given to the colliery proprietor to enable him to open up to the nation its mineral wealth.

Although the writer has quoted Prof. Galloway and Mr. F. G. Meachem, he does so simply to show that the principle of national interest in mineral value is mooted by them, and, in addition, the latter further hinted the desirability of a national subsidy to assist in getting minerals which would otherwise be lost. The writer does not, however, altogether agree with their mode of expressing themselves. Prof. Galloway said:—"I should take it that the coal is really the property of the community generally." In the writer's opinion, it would be nearer the truth to say that the mines are the property of the colliery proprietor, to the extent of the proportion of his profit to the selling price of the coal, the rest belonging to the community generally. The mine-owner has now thrown on his shoulders not only the responsibility of preserving other people's property on the surface to the extent of sacrificing his own and that of the community, but must also bear the cost of any real or often alleged damage, while the community generally stand by approvingly, not realizing the fact that the mine-owner is fighting their battle, and that they are the losers as well as the mine-owner.

Having proceeded thus far, the writer now goes a step further, and though his suggestions may appear crude and somewhat impractical to some, yet if the raising of this important subject be the means of provoking a discussion, and thus ventilating the matter, some other and more practical way of dealing with the problem may be brought to light.

If a property should be threatened with damage or destruction by the working of minerals under or subjacent to the property, the property threatened should be valued by independent valuers appointed by the Government, and also the portion of the mines required for the support of the property to be valued. This valuation should be made on, say, two-thirds of the value of sale-tons at the low rate of 1,200 tons per acre. If the value of the mines on this basis exceeds the value of the surface property, then the mines under and subjacent to the property should be worked, and the surface-property owner compensated for the damage done to the property. Such damage should be estimated by the aforesaid values, and, in case the property is completely destroyed, the full value of it should be paid.

For the purpose of assessing the amount to be paid by the mine-owner or lessee, as the case may be, the area of the mine

necessary for the support of the property—the radius of such area from the property to be supported to be not more than half the depth of the seam—should be estimated. An estimate based on the result of the previous year's working should be made of the profits per acre on the area indicated above. The mine-owner should pay a sum not exceeding one-third of the profits, as estimated on that area as his share, if the property is totally destroyed; but if the property is only damaged, then such a proportion of that sum as the amount of compensation for damage bears to the value of the property. The remainder of the compensation, if any, should be paid by the State as the share of the community generally. By some such means expensive litigation would be avoided, and property-owners compensated, and this without crippling the mine-owner. The rights of the community generally in their share of the national wealth would be met, as it would profit by employment, by trade generally, by the rates and taxes paid, and by the benefiting of contingent industries through the working of minerals which would otherwise be lost.

As to the freeing of mines from water, if the State appointed a committee of experts to assess the value of the minerals submerged, at, say, two-thirds of the market value, the State should advance a sum of money not exceeding one-third of such value, for the purpose of freeing the mines from water. A rate, which the writer would suggest should not exceed 6d. per ton, should be imposed on all minerals raised from the hitherto submerged area, the remainder of the cost, if any, to be the contribution of the community generally. Thus the money would be used absolutely for the purpose required, the interest and sinking-fund being the additional national wealth recovered to the nation.

If some such scheme could be devised for this district, the benefit derived therefrom would be enormous; and the fear of an early exhaustion of the minerals in its area and consequent industrial ruin would be postponed for some generations.

The PRESIDENT (Mr. J. C. Forrest), in proposing a vote of thanks to Mr. Meachem, suggested that, as another paper was to follow, the discussion should be deferred until the next meeting.

Mr. ALEXANDER SMITH (Birmingham), in seconding the vote,

remarked that it was a very important paper, and one that required a thorough discussion. He agreed with Mr. Meachem that something ought to be done to prevent the loss of minerals that were left for support of the surface, etc. He personally knew of many cases where pillars had been left that were, in his opinion, larger than necessary. He also thought that legislation might be introduced to prevent the national loss due to mineral-owners who refused to allow their minerals to be worked when the adjacent mines were gotten, thus causing irretrievable loss.

The vote of thanks was heartily accorded.

Mr. T. A. O'Donahue read the following "Notes on the Valuation of Mineral Properties":—

NOTES ON THE VALUATION OF MINERAL PROPERTIES.

By T. A. O'DONAHUE.

Introduction.—The question of the valuation of mineral estates has by reason of recent legislation been raised to one of considerable importance. Hitherto valuations of such properties were not frequently required, and in the few cases which necessitated a valuation the mineral valuer's estimate had seldom to be subjected to close criticism. For this reason the matter has received only spasmodic attention, but as the mining engineer is now frequently called upon to make valuations, and, what is a still greater factor in the case, as an agreement between opposing parties has to be made, the time has arrived when it is essential that the same general principles should be applied to such valuations. The speculative character of mineral property admits of opinions divergent enough of themselves to occasion obstacles to agreement as to value, without the case being further burdened by basing the calculations on conflicting principles.

It is some 35 years since the publication of the late H. D. Hoskold's work,* which dealt more or less exhaustively with the principles of valuation as applied to speculative properties; and, so far as the mining engineer was concerned, the subject received little further attention (if the absence of any publication on the subject may be taken as a criterion) until the writer's papers were published in the *Colliery Guardian*† and in the *Transactions* of the Institution‡ in 1906.

It is not his present purpose to review in detail the points then raised, which referred more particularly to the valuation of deferred annuities. Sufficient it is to say that it has been shown that formulæ, embodying the same principles as those then submitted by the writer from independent conclusions, had been pre-

* *The Engineer's Valuing Assistant*, 1877.

† 1906, vol. xci., page 271.

‡ *Trans. Inst. M. E.*, 1906, vol. xxxii., page 399.

viously deduced by an eminent actuary and adopted by others, and that the Estate Duty Department gave its approval to the principles laid down as being those for which the Department contended. It may be desirable to state here that the writer had not the remotest connexion with the Department at that time, and, further, that the views here expressed are purely personal ones, as the writer has no authority to speak for anyone except himself.

In the present paper the writer, with a view to the establishment of uniform methods, proposes to refer to various points of principle on which differences of opinion exist. Before proceeding to discuss these, it is necessary to present what may be regarded as axioms of finance. On these axioms the whole structure of the principles of valuation is based, and it is because these elements are not properly appreciated that so many erroneous views obtain.

Interest.—The rent or profit paid to the capitalist for the use of his capital is the interest.

Accumulative Rate of Interest.—The positive accumulative rate of capital is decided by the increments due to the interest which can be obtained from an investment in which the principal and interest are absolutely secure. Theoretically, no such security exists; but, for practical purposes, the accumulative rate may be taken to be that rate which may be realized with a maximum of security such as that obtained from Consols. The restriction of trust funds to certain securities reduces the rate of interest thereon to something less than the accumulative rate, but the wide extension of such securities in recent years has reduced the difference to a negligible quantity.

Remunerative Rate of Interest.—When the security of the investment is doubtful, the capitalist bargains for a remunerative rate of interest which is higher than the accumulative rate; the excess being the amount required as *insurance* for the risk taken. It may be argued that the remunerative rate of interest also includes the lender's remuneration for his work of making the investment, etc.; but this point may be neglected, as it does not affect the general conclusions to be drawn.

The market rent of capital is the accumulative rate of interest. Any interest bargained for in excess of the accumulative rate is for *insurance*: the lender may employ the excess to insure his

investment, or he may decide to take the risk himself; but the insurance must not be regarded as profit naturally accruing to the capital. It may be logically concluded that a transaction which, when closed, yields anything greater than the accumulative rate of interest has been, in a measure, successful, no matter how much it falls short of yielding the rate of interest originally bargained for, and that the average return on capital in any particular industry should be approximately the accumulative rate of interest. If it be assumed that an investor applies the excess to insure his investment, then he is left with exactly the accumulative rate of interest as profit for his capital. If, however, he decides to take the risk himself, he may lose the whole of his capital, or he may realize the high rate of interest for which he bargained. Assuming that the insurance premiums of an indefinite number of cases were pooled, theoretically there should be no profits: the premiums from the successful cases should exactly meet the losses in the other cases.

Profits of the Coal-mining Industry.—It has been demonstrated by several investigators that the mining industry of this country, taken as a whole, yields dividends little, if any, in excess of the accumulative rate of interest, after allowing for the redemption of capital.

The Board of Trade publish a return showing more or less reliable data from which a fairly accurate estimate of profits can be made. Analysing the Board of Trade's figures over a period of 15 years (1886-1900), Lord (then Sir James) Joicey attempted* to disabuse the public mind of the idea that the mining industry, taken as a whole, yielded high profits. The summary figures of the returns with which he dealt are as follows:—

PERIOD OF 15 YEARS FROM 1886 TO 1900.

Total output, in tons	2,802,395,000
Value at the pit's mouth	£953,477,000
Average value per ton	6s. 9·65d.
Expenditure on wages	£642,386,000
Average expenditure on wages per ton	4s. 7·01d.
Remaining for expenses other than wages and for coal-owners' profits	£311,091,000
Do. do. do. per ton	2s. 2·64d.

To deduce the coal-owners' profits, Lord Joicey, so that he should not overstate his case, took only 1s. 6d. per ton as the

* *The Times*, May 22nd, 1901.

expenditure in materials, rents, salaries, etc., but he pointed out that the experts agreed that this should be at least 1s. 9d. Deducting 1s. 6d. from the value per ton remaining for expenses and profits, the profit per ton is 8·64d. The capital invested is difficult to determine, but Lord Joicey gave £110,000,000 as a low estimate for the period under consideration. This works out at 11s. 9d. per ton produced annually, and taking the profit at 8·64d. per ton, the interest is practically 6 per cent., without allowing for redemption of capital.

Dr. J. B. Simpson in 1898 estimated the capital invested at from £80,000,000 to £100,000,000, and after an examination of the Inland Revenue returns over a period of 30 years, he concluded that the profit was about 6d. per ton, or 5 per cent. upon the capital invested, without allowing for redemption of capital.*

In an article on the subject, in the *Colliery Manager's Pocket Book* for 1903, a writer estimated the capital value per ton for the United Kingdom at 10s. He gave more particular consideration to the County of Northumberland for a period extending from 1880 to 1900, and estimated the capital value as 9s. per ton and the profits as 3 per cent., or, without redemption, 5 per cent.

Mr. T. Good has also dealt with the subject,† and his conclusion was that the yield of interest was not more than 3 per cent., after allowing for redemption.

Prof. J. H. Merivale fixed the profit per ton at 6d., without taking redemption of capital into account.

From the Income Tax returns for 1909, Sir Arthur Markham, Bart., M.P., estimates‡ the gross profit to be 8¼d. per ton.

The writer has taken into consideration the full period from 1886 to 1910 inclusive. Such a period is sufficiently long to eliminate errors due to years of good and bad trade. The Board of Trade returns give the output and the value at the pit's mouth for each year of the period; but, so far as the writer is aware, the estimated expenditure on wages has not been published beyond 1902. A report is made annually, however, of the changes in rates of wages. This affords data similar to those on which the Board of Trade estimated the expenditure on wages from 1886 to 1902, and from this information the writer estimates the

* *Capital and Labour in Coal-mining during the past Two Hundred Years*, by John Bell Simpson, 1900, pages 10 and 25.

† *Cassiers Magazine*, 1906, vol. xxix., page 370.

‡ *Manchester Guardian*, February 13th, 1912.

expenditure on wages for the years 1903 to 1910 inclusive at £550,300,000, which added to the total of the Board of Trade's figures for 1886 to 1902 inclusive, namely, £767,440,000, gives a total of £1,317,740,000.

The summary figures for the 25 years comprised in 1886-1910 are as follows:—

PERIOD OF 25 YEARS FROM 1886 TO 1910.

Total output, in tons	5,256,124,000
Value at the pit's mouth	£1,946,928,000
Average value per ton	7s. 4·9d.
Expenditure on wages	£1,317,740,000
Average expenditure per ton	5s. 0·1d.
Remaining for expenses and profits	£629,188,000
Do. do. do. per ton	2s. 4·8d.

It will be seen that the estimated expenditure on wages is practically 68 per cent. of the value of the coal at the pit's mouth. This would appear to be fairly accurate; for 70 per cent. is usually taken in practice as representing in round figures the proportion paid in wages.

After taking into consideration, however, the sources of information from which the Board of Trade returns of selling-prices are compiled, the writer is of the opinion that the figures of value are a little too low. It is also probable that the returns of wages are rather high, as these are calculated on percentages of increases above the standard, and all the workmen have not fully participated in the increases.

Lord Joicey's deduction of 1s. 6d. per ton for expenses other than wages is, as he himself remarked, low. As regards the amount paid for royalty rents, this can now be determined with reasonable accuracy from the recent returns of revenue produced by Mineral Rights Duty, and the average royalty per ton on this basis is estimated to be about 5½d.* It will be readily admitted that 1s. 0½d. per ton would not meet other costs, even for the period dealt with by Lord Joicey: 1s. 3½d., as fixed by the experts, would be much nearer the mark. For the reasons stated above, however, it is probable that Lord Joicey's final figures of profits do not err greatly, as the deduction of 1s. 6d. instead of 1s. 9d. would balance the error of the Board of Trade figures.

For the extended period, from 1886 to 1910, the costs of

* The Chancellor of the Exchequer stated in the House of Commons on March 6th, 1912, that 5½d. per ton was as near the mark as could be estimated.—T. A. O'D.

materials, etc., cannot be put at less than about 1s. 5d. per ton, and it is probable that 1s. 7d. would more nearly represent the true figure for the present day; but, to allow a correction on the Board of Trade figures, the writer has adopted 1s. 2½d. per ton as the cost of materials, etc., making, with the royalty of 5½d. a ton, a total deduction of 1s. 8d. per ton.

From experience in several coal-fields, the writer concludes that the average capital value per ton cannot be put at less than 12s. 6d. A capital value of 10s. per ton is low for the average colliery, and when it is considered that large sums are frequently lost in undertakings which are initially failures, an average capital value of 12s. 6d. per ton is none too high.

On the basis of a deduction from the Board of Trade figures of 1s. 8d. for expenses other than wages, there remains 8·8d. per ton as profit, or 5·86 per cent. on a capital value of 12s. 6d. per ton. If the term to be allowed for the redemption of capital be taken as 30 years, about 2 per cent. is required, which reduces the net profit to 3·86 per cent.

It may be objected that the figures from which these conclusions are drawn are mainly hypothetical; but, in the writer's opinion, they are the best available, and the conclusions are exactly what the theory of finance leads one to expect. The writer is aware that two gentlemen have recently produced a small book* in which they try to show that the profits of the coal-trade are far in excess of those here given, but their conclusions would not appear to be convincing.

The Two Rates of Interest Fallacy as Applied to Immediate Annuities.—When valuing mining properties, it is customary and proper to capitalize the revenue as an annuity certain, that is, as an annual payment which will be made for a certain number of years. If the present value of an annuity certain, taken at a normal rate of interest, be required, it is almost invariably calculated at one rate of interest; but, if the stipulated rate of interest is a high one, a lower rate is frequently taken on which to calculate the redemption fund.

It is clear that the annual payments of an annuity certain must provide not merely the stipulated rate of interest on the capital, but also such an additional sum as will replace the

* *Profits and Wages in the British Coal Trade*, by Thomas Richardson, M.P., and John A. Wallbank, F.C.A.

original capital by the end of the term when the annuity ceases; for the purchaser bargains for the return of his capital as well as interest thereon. The writer grants at the outset that there should be no risk involved in the redemption of the capital apart from the risk of the original transaction, and it is not to this point that objection is taken.

Various views obtain as to what the single rate of interest allows, and it has even been put to the writer that it makes no provision whatever for the redemption of capital. It is profitless to go into the history of the introduction of the theory that a second and lower rate of interest should be taken on which to calculate the redemption fund. It will suffice to say that it was H. D. Hoskold (supported by the eminent actuary Peter Gray) who was mainly responsible for its introduction and adoption amongst mining engineers. Messrs. Hoskold and Gray stated their views on the subject very fully, and the reasons given appear to be very conclusive; at any rate, they were so regarded by the writer until he gave them close investigation. To avoid understating the case which the writer wishes to controvert, extracts are given below from Mr. Hoskold's and Mr. Gray's contentions.

Mr. Hoskold's conclusions are as follows:—

"It is stated on page 2, in all the editions of 'Inwood's Tables of Annuities' that I have seen—that is to say, those published from 1837 to 1866—that 'A lease or annuity for 14 years, to make 3 per cent. and get back the principal, is worth 11·296 years' purchase of the clear annual rent,' and this rule is repeated as a foot-note as far as page 9, as being true for all the rates of interest up to 10 per cent."

"This table, and others of its kind, to be found in most works on Annuities, is constructed correctly according to the mode laid down; but as that mode is based on incorrect principles, its application to the valuation of annuities, where interest is allowed at higher rates per cent. than can possibly be found for reproducing capital, is entirely fallacious, for the principle upon which it is based assumes that we can reproduce capital which may have been invested, at the same rate of interest as that allowed and expected to be realised on the purchase money invested."

"Tables of this class are, therefore, limited in their use to cases where the rate of interest on the capital invested, is the same as that which may be practically obtained in the funds for redeeming the capital."

"The question is, as I have before said, of vital importance, and may, I think, be so far demonstrated as to put it beyond a doubt or mere matter of opinion; and by employing the proper rule previously referred to and laid down in this work, the truth may possibly appear more clear and convincing by deductions arrived at from numerical examples."

"Taking 3 per cent. as interest to be realized on capital invested, and

redeeming that capital at the same rate within 14 years, we have the redemption fund to reproduce the capital at 3 per cent. within 14 years = 0·05852634."

"Then 0·05852634 plus 0·03 = 0·08852634 and $\frac{1}{0{\cdot}08852634}$ = 11·29607314 years' purchase, practically the same as in Inwood, and in all other writers on Annuities, but correct to more places of decimals."

"Now, assuming a purchase was effected by allowing 20 per cent. instead of 3 per cent., and by the same rule also to recoup at 20 per cent., we have the redemption fund to recoup at 20 per cent. within 14 years = 0·0168930552."

"Then 0·0168930552 plus 0·20 = 0·2168930552 and $\frac{1}{0{\cdot}2168930552}$ = 4·610567171 years' purchase."

"Suppose the annuity to be purchased equals £20,000, its present value, immediate, would be £4·610567171 × 20,000 = £92,211·34342."

"Then 20 per cent. upon this sum = 18,442·268684

"And £92,211·34342 × 0·0168930552 = 1,557·731316

The annuity ... ... £20,000·000000."

"It is, therefore, evident that if a purchaser were to invest £92,211·34342 in purchasing an annuity of £20,000, derived from some mineral property, he could not invest annually in any funds so small a sum as £1,557·731315 for 14 years, that would yield him 20 per cent. It would, therefore, be impossible to realise or reproduce the original capital invested, within the time, under the circumstances."

"The practice, therefore, of valuing upon tables constructed on the assumption of reproducing capital at the same high rate of interest, as that which may be realised on it, is opposed to the truth, and calculated to mislead and injure a purchaser to a very large extent."*

Mr. Gray deals with the subject as follows:—

"It cannot be doubted that the purchaser of an annuity for a term, on which he is to be allowed interest at a specified rate, ought, as regards this transaction, to be in the same position, pecuniarily, at the end of the term, as if he had lent his money during the term at the same rate. The lender receives his interest annually, and has the sum lent returned at the end of the term. But the purchaser of an annuity must recoup himself by investing the excess of his annuity over the annual interest on his outlay, at such a rate that at the end of the term his capital will be reproduced. The lowest rate at which this reproduction can be *assumed* by the vendor or purchaser to be effected, is the rate allowed in the purchase of the annuity, as will presently be shown. In the case of annuities purchased at current rates, but little inconvenience and loss will occur to the purchaser from this restriction as to the rate of re-investment, since *practicable* rates in respect of such will usually differ but little from the *stipulated* rates. In the cases with which we are here concerned, however, the state of matters is far otherwise. In the purchase of mining property the purchaser, for reasons with which we have nothing here to do—they are fully discussed in the following work—is usually, perhaps always, allowed a rate of interest on his outlay far exceeding that at which he can invest the surplus of his annuity, which is called with propriety the *Redemption Fund;* and hence, if the *ordinary tables* are used in the valuation of the annuity determined and assigned by the valuator, the result must be a loss to the purchaser, more or less heavy according to circumstances, since in them the difference between the two rates is ignored."†

* *Op. cit.*, pages 50-54. † *Ibid.*, pages xvi-xvii.

The above conclusions appear to be difficult to refute, but they are founded on half truths, and have been built up on premises which were taken for granted, but which by no means can be taken for granted.

It has been assumed that it is logical to allow the stipulated rate of interest on the original capital for the whole of the term, despite the fact that a portion of the capital is returned each year. The purchaser cannot logically be entitled to the extra interest which represents insurance on capital which he has in his own possession. A simple example will illustrate this more clearly. It can probably be put more forcibly if it be assumed that the person who sells the annuity has to provide the annual payments as they become due: the purchaser of the annuity is then in the position of the capitalist who effects the loan, the interest and capital of which has to be returned by equal instalments over a period of years.

"X" lends £1,000 to "Y," and it is agreed that "Y" shall pay 10 per cent. interest and return the capital by five annual instalments of £200 each. At the end of the first year "Y" pays the instalment of £200 on the capital and £100 as interest, being 10 per cent. on the £1,000. At the end of the second year "Y" again pays the instalment of £200 on the capital, but the question arises as to what amount is payable for interest. "Y" very naturally says: "I have had during the year £800 belonging to 'X,' and obviously the interest due at the rate of 10 per cent. is £80." It would certainly be considered inequitable for "X" to demand a further £14 from "Y," because the £200 received in the preceding year had been invested in sound stock at 3 per cent., and had yielded only £6. The excess 7 per cent. stipulated for at the outset was for insurance, and "X" cannot in equity demand the payment of insurance on moneys in his own possession or at his own discretion.

It may be argued that it is a question which should be defined in the terms of the agreement, but the writer cannot agree that this is the proper method. Of course, it is open to the parties to make any conditions that they deem fit; but what the writer desires to emphasize is, that if it be agreed that the full interest on the original capital shall be paid for the full period of the loan, then the 10 per cent. does not represent the true measure of the rate of interest which is to be paid. The writer must not be under-

The showers at present provided are as follows:—For adult miners, 130; for youths, 6; and for surface-men, 12; making a total of 148. The arrangement is such that the number of showers and of suspenders can be increased to provide for a total of 5,000 men, as the development of the mine progresses.

The length of the building for the underground workmen is about 294 feet, the width being about 60 feet, and the showers provided are all contained in one aisle at one side of the building, and arranged in pairs on either side of a pipe running the whole length of the building. To increase the accommodation for drying and dressing, a second storey, reached by a spiral staircase, has been built above the aisle where the showers are provided. The pin-stands are set lengthways down the building, and light and air are obtained through large windows in the wall opposite the washing side.

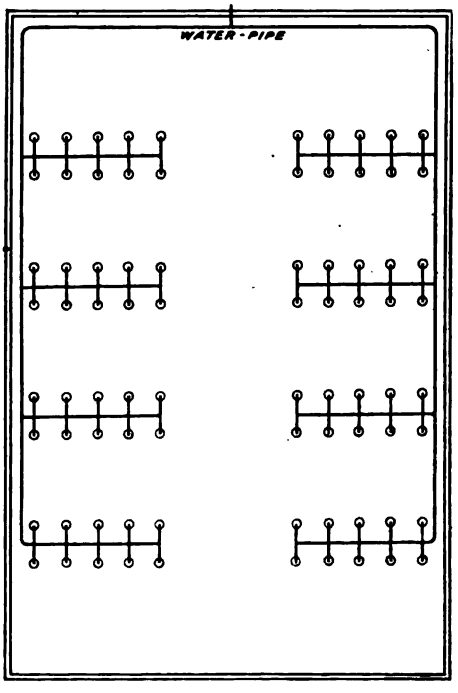


FIG. 17.—SKETCH-PLAN OF BATH-ROOM, SHOWING ARRANGEMENT FOR EIGHTY SHOWERS. SCALE, 20 FEET TO 1 INCH.

Other Installations.—At another colliery in Westphalia there are similar arrangements, accommodation being provided for 2,000 men in three shifts. The building measures about 132 by 51 feet, and there are fifty-four showers, all placed on one side; the pin-stands are set lengthways down the building.

In Belgium an excellent installation of baths is to be seen at one of the pits of the Monceau Fontaine Company, near Charleroi, and the writers are indebted to Mr. Moreau, the general manager of the company, for the accompanying plans (Fig. 1, Plate I.; and Figs. 2 to 5, Plate II.) and information.

Accommodation is provided for 800 men, and there are at

present 102 showers, but space has been allowed for the addition of more. The building is 123 feet (37·50 metres) long by 74 feet (22·555 metres) in width, the height of the roof-ridge being 39 feet (12 metres). In general design it is similar to that at the Rhein-Preussen and Ickern Collieries, the shower aisles being built along each side of the building, but in this case each shower has its separate cabin. The aisles each occupy a width of 16½ feet (5 metres), leaving a central area 41 feet wide and 123 feet long (560 square yards), which is used for dressing purposes and for hanging up the clothes.

Metal boxes as previously described (Fig. 11), are provided for the slack of the suspender-chains.

The cabins (Fig. 16), built of glazed bricks, are 39½ inches (1 metre) wide by 5 feet 4 inches in length, and are provided with a little outer compartment containing two or three hooks and a seat. Openings in the walls, about 1 foot high, are left next to the floor, which allows of the water running away, and also permits of freer ventilation. All joinings are made with a bevel, so as to avoid any sharp angles where dirt may accumulate. A stout canvas curtain hung from an overhead rail can be drawn across the entrance to each cabin. The total first-cost of this establishment was stated to have been £4,800 (120,000 francs), or £6 (150 francs) per suspender. It is an unusually spacious and handsome installation.

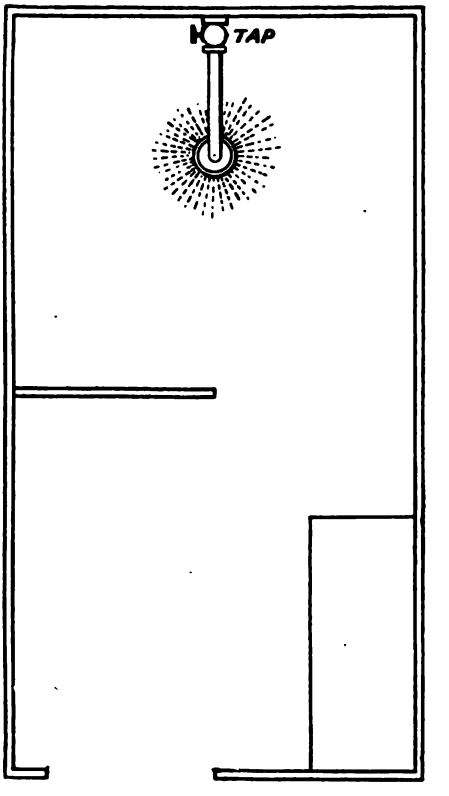


FIG. 18.—BATHING-CABIN.
SCALE, 1½ FEET TO 1 INCH.

At the Quesnoy Pit of the Bois du Luc Company, Belgium,

the bathing installation comprises two separate buildings, one for washing and the other for dressing, communicating with each other by a short passage. About 500 men are at present using the establishment, and the bathing-hall is 69 feet (21 metres) long, 46 feet (14 metres) wide, and 23 feet (7 metres) high.

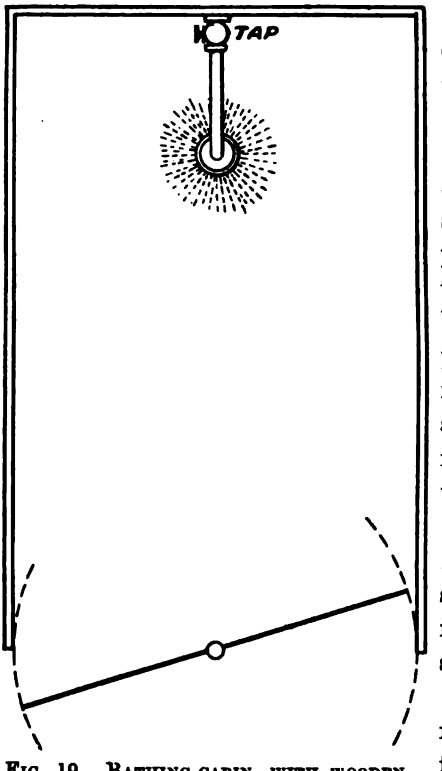


FIG. 19.—BATHING-CABIN, WITH WOODEN SWING-DOOR. SCALE, 1½ FEET TO 1 INCH.

There are eighty showers, arranged in sets of ten, from eight branch-pipes (Fig. 17), each pipe being about 15 feet in length, and carried out from the side walls in a direction parallel to the width of the building. From the branch-pipe five short pipes, each about 2 feet in length, project at right-angles on either side, terminating in the roses for the showers.

The eighty cabins (Fig. 18) are made of painted sheet-iron, and are grouped in sets of ten, one to each shower.

The dressing-hall is 75 feet (23 metres) long, 46 feet (14 metres) wide, and 41 feet (12½ metres) high. The suspender-pins are fixed along the side walls, and it is considered that there is room for 1,000. Twelve wooden benches are arranged about the hall.

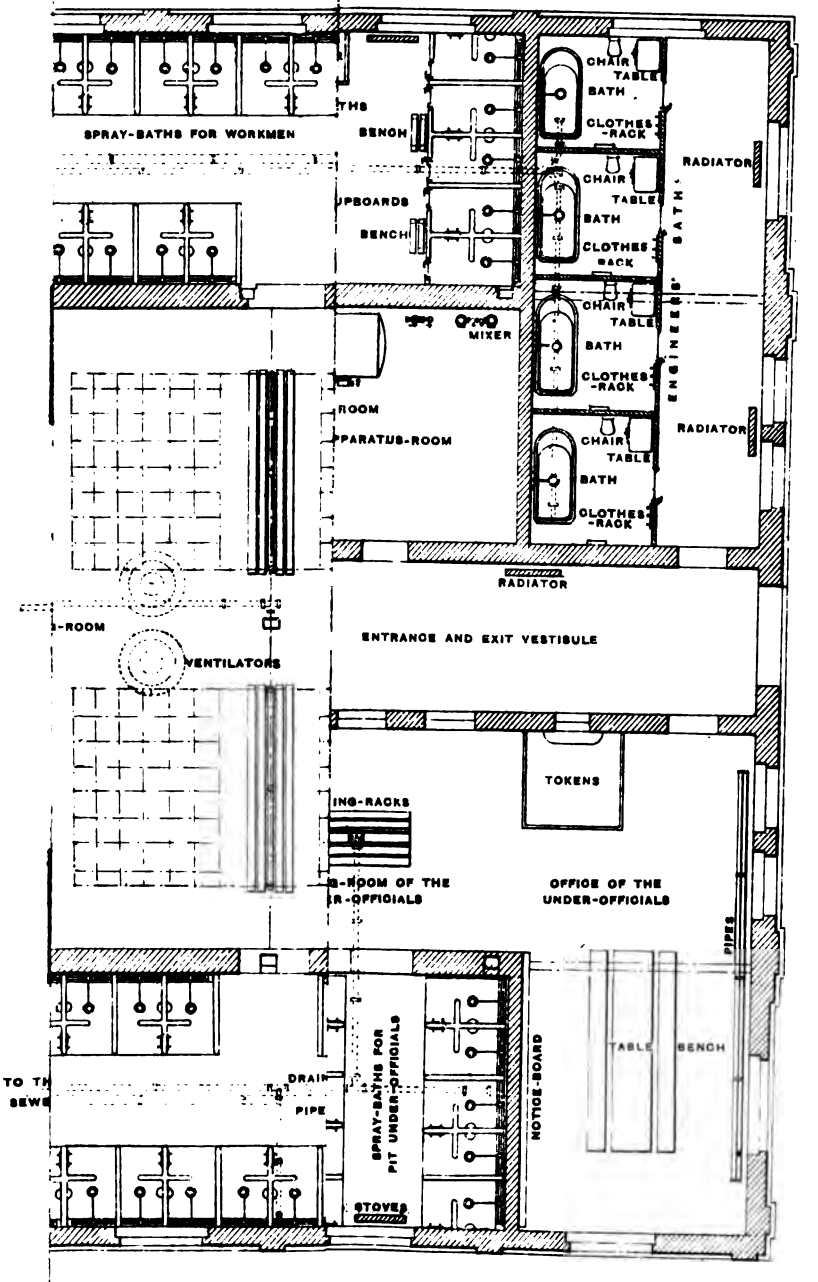
Mr. Kuss gives the cost of this installation as follows:—*

	Dressing-hall. Francs.	Washing-hall. Francs.	Total. Francs.
Ground	1,785	1,765	3,550
Buildings	26,000	25,600	51,600
Fittings	7,078	17,548	24,626
	34,863	44,913	79,776
	(£1,395)	(£1,796)	(£3,191)

* "Note sur les Installations de Bains-douches pour les Ouvriers Mineurs, en Belgique," by — Kuss, *Annales des Mines*, Paris, 1911, vol. xix., page 5.

son's Paper on Miner's' *Vol XLIII, Plate I.*

ITS OF THE SOCIÉTÉ ANONYME LGIUM.



Vol LXII, Plate II.

IS AND LAMP-ROOM, AT T
MONCEAU-FONTAINE, BE

FIG. 3.—BACK ELEVATION OF BATHS.

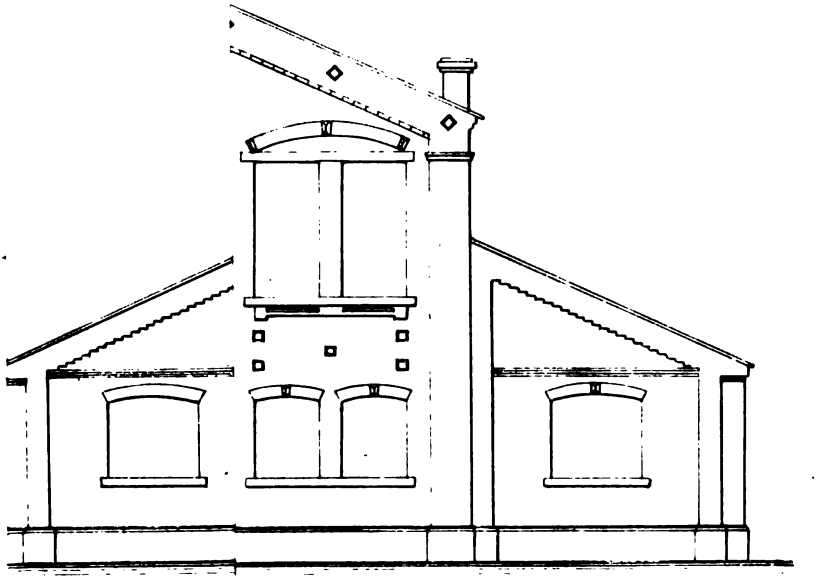
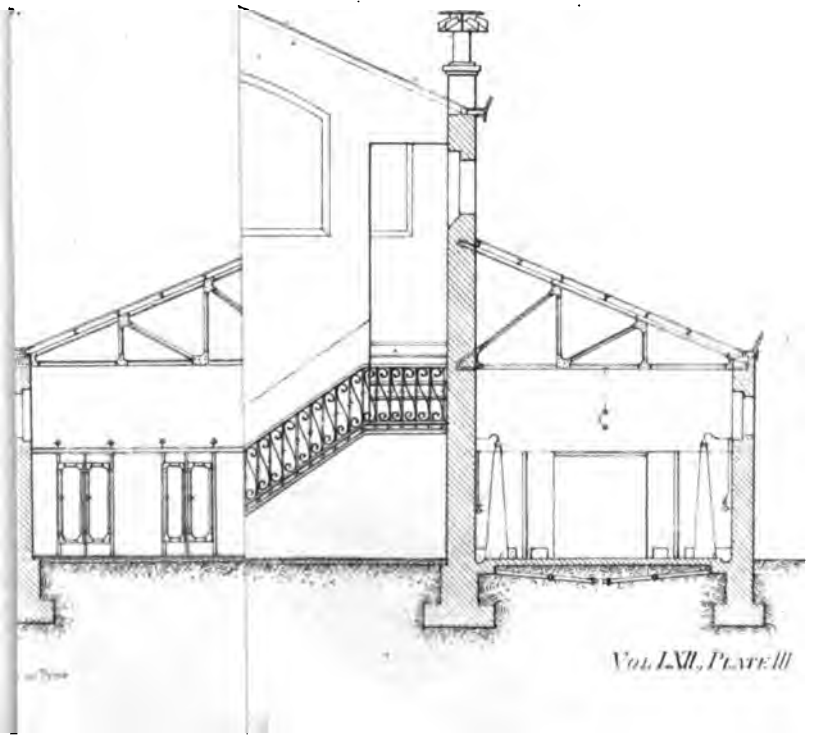


FIG. 5.- SECTION ALONG LINE C D OF FIG. 1. PLATE 1



This total sum of £3,191 is the first-cost of this installation of eighty showers and 800 suspenders, equal to about £4 per suspender or man using the baths. Mr. Kuss considers that £4 to £4 16s. (100 to 120 francs) per suspender is the average cost of a new installation of any importance in Belgium.

At one of the newest collieries (Fosse No. 13 of the Lens Company, Pas-de-Calais) an installation of baths has been recently carried out. A fine brick building, well lighted and ventilated by large glass windows running continuously along its two sides in the upper half of the walls, is provided. It is 78·7 feet (24 metres) long, 36 feet (11 metres) wide, and 21 feet (6·50 metres) high to the top of the walls, the total height to the roof-ridge being 33 feet (10 metres).

The building provides for 650 men in two shifts; there are 650 suspenders and 56 showers; the latter are placed around the walls of the building, with a separate cabin for each shower.

The cabins of white glazed bricks (Fig. 19) are 39½ inches (1 metre) wide, 5 feet (1½ metres) long, and 6¼ feet (1⅞ metres) high, with no separate compartment. The entrance to each cabin is provided with a wooden door, arranged so as to turn easily around its central vertical axis on pivots fixed above and below. To one side of the door are fixed four hooks for hanging clothes, which can thus be turned outside to avoid getting them wet when the bather is washing, and inside when he wants them.

The central portion of the building is used for changing the upper garments, and for keeping and drying the clothes that are left, in the manner already described.

It is evident that the number of showers provided must depend upon the largest number of men coming out in one shift, and on the time which they take to come out, as a man cannot be expected to wait for his bath very long. The number of suspenders must equal the total number of men using the establishment.

Prof. Henry Louis (Armstrong College, Newcastle-upon-Tyne) said that the authors mentioned that the washing arrangement always took the form of a fine shower or spray, and it might be interesting to point out that that was not the original form.

At first, in Germany, plunge-baths were used, but it was found that contagious diseases, particularly of the eye, were communicated by this means, and therefore the law made the use of shower-baths compulsory in Germany. In view of the possibility of baths being adopted in this country, it would be well to remember that the Germans had gone through this experience. In one or two collieries in Westphalia, where he had seen the bathing arrangements, there were seats made of enamelled cast-iron or concrete below the sprays, so that the men could sit down when washing. Another point in the paper to which he might refer was the statement that very few padlocks were in use; that did not altogether agree with what he (Prof. Louis) saw and was told. He had been told that they had a great deal of trouble in Westphalia, owing to the prevalence of a certain amount of pilfering. They were now very careful, and had instituted a rule that every chain must be padlocked, but that each miner must provide his own padlock and key, and therefore be responsible to himself that he provided a padlock that could not be picked. Finally, he would like to draw attention to the fact that in all the metal-mines in this country it had been the custom for a great number of years to have what was called a "dry." In all the Cornish mines, and in most of the lead-mines and ironstone-mines, and, indeed, he thought, in all the mines under the Metalliferous Mines Act, a "dry" was provided in which the man changed his clothes. A man never went home in the clothes in which he worked underground, but changed them when he came up, and his working clothes were left in the "dry," which was a room heated by steam-pipes, where he found them dry when he came back to work next morning. He did not know of any of those mines where baths were provided in addition to the "dry."

Mr. C. H. Merivale (Middleton Colliery) said that Mr. Bulman had mentioned glazed bricks and tiles. One of the difficulties would be to get the men proper privacy; they would not wash in a crowd, but would want privacy, and that meant partitions. Tiles were made now with locking joints, very narrow, not more than an inch wide, and there would be no difficulty in making partitions of tiles, slung from wire rods, which would not occupy much space, and that would overcome the difficulty of considerable extra expense in making partitions. He had tried

to get the men at Middleton Colliery to adopt the bath system, and had offered them partitions, but they objected to the whole arrangement.

Mr. JOHN H. MERIVALE (Acklington) said that his experience of pit-head baths went back 40 years, and he altogether endorsed what Prof. Louis had said. In Belgium they did not use the spray at all collieries: at some each man had a wooden bath, or tub, in a small cubicle. The last occasion on which he had had to speak on the subject was in a different atmosphere, where they were all strictly commercial, and that might be his excuse for saying that he was the only man there who approved of compulsory baths. Looking in the direction in which things were trending, he was inclined to think that they would have to supply their men with baths. For many reasons he thought that it would be an excellent thing if they did, and, unless they made such arrangements as had been described by the writers of the paper, they would have to put baths in the workmen's houses. His experience corresponded with what Mr. Bulman had said as regards the cost, namely, £4 or £5 per hand employed, and he did not think that they could put baths into the existing houses at anything like that figure. There were, however, two other reasons—not commercial—which inclined him to be favourable to pit-head baths: one was that they made it much more comfortable and convenient for the women; and, again, they all knew that the coal-miner, with very few exceptions, had a longer expectation of life than any other working-man, the reason, he believed, being that he had plenty of work, plenty of food, and plenty of washing. But he did suffer more than many others from bronchial troubles, and he (Mr. Merivale) believed that that was largely due to his standing about after coming out hot from the mine. Some of them walked home, but a large number went away in draughty vans. If they had the bathing accommodation established at the pit-head, that tendency to bronchial troubles would disappear, as the miner would change and go home in dry clothes; and for those reasons he (Mr. Merivale) was strongly in favour of the compulsory provision of baths.

Mr. C. H. STEAVENSON (Redheugh Colliery) said that it would be interesting if the authors of the paper would give the members

some idea as to the cost of maintenance. There was nothing mentioned excepting the initial cost of installation of the baths.

The PRESIDENT (Mr. M. W. Parrington) said that one point that struck him with regard to baths was the comparison between the working-cost of the same and what they had to pay for water. There was another point, and that was the nature of the water. One might get one's self fairly clean with 6½ gallons of Newcastle water, but he was doubtful whether that could be accomplished with 6½ or even 8½ gallons of the hard limestone water of County Durham. The kind of water used must make a huge difference either in the consumption or in the result.

THE MANCHESTER GEOLOGICAL AND MINING SOCIETY.

GENERAL MEETING,

HELD IN THE ROOMS OF THE SOCIETY, QUEEN'S CHAMBERS,
5, JOHN DALTON STREET, MANCHESTER,
FEBRUARY 13TH, 1912.

MR. GEORGE B. HARRISON, PRESIDENT, IN THE CHAIR.

The following new members were elected, having been previously nominated:—

MEMBERS—

Mr. GEORGE KNOX, Lecturer on Mining and Geology, Mining College, Wigan.

Mr. LLEWELLYN E. WILLIAMS, Colliery Manager, Manchester Road, Chequerbent, Bolton.

The following paper on "A Dust-fuel Boiler and its Uses" was read by Mr. HUGH V. HART-DAVIS:—

A DUST-FUEL BOILER AND ITS USES.

By HUGH V. HART-DAVIS, A.M.I.Mech.E.

Introduction.—Coal-dust is one of the many difficulties with which mining engineers have to contend. Much has been done, and is still being done, towards the collection of coal-dust below ground, but at few mines are any steps taken to collect this dust at the surface. At many collieries the screening-plants are situated near the downcast shaft, and the weight of coal-dust that is carried down these shafts in a year must be considerable.

Coal-dust, when analysed, is found to be of high calorific value, and should be, therefore, by no means a waste-product, as it will amply repay the cost of collection, if it can be successfully consumed.

It has long been known that an almost perfect combustion can be obtained by the introduction of finely-pulverized coal, with a correct proportion of air, into a heated furnace. Attempts have been made in the past to burn dust by blowing it into the furnaces of Lancashire boilers, but it was found that the flues soon became filled up with partly-consumed dust, and that the output of the boiler was consequently reduced. Other methods have been tried, but it has been found impossible to keep intact the brickwork with which the furnace is surrounded. Up to the present, therefore, the use of pulverized fuel was limited to the burning of cement in special kilns, no commercial success having been established in its use for firing boilers. A plant that has successfully overcome these difficulties has been erected at the Outwood Collieries, near Manchester, and is now described by the writer.

Coal-dust Collection.—At the collieries there is one screening-plant for the three shafts. The coal-tubs run by gravity to the tipplers, four in number, the large coal passing through the screens to picking-bands, and the small falling on to a curved rubber belt, by which it is conveyed into railway-wagons, and then sent to the washery.

A complete system of dust collection (Figs. 1, 2, and 3, Plate III.) has been installed. A fan, 25 inches in diameter, running at 680 revolutions per minute, and driven by a 12-horsepower motor, produces the suction required, and delivers the coal-dust into a large cyclone collector, some 20 feet high and 10 feet in diameter. The air and dust enter the collector at the side, and the air being made to revolve, the dust separates and descends by gravity to the bottom of the cone, while the air is expelled at the top. Galvanized-iron pipes of suitable diameter for carrying the dust are led from the tipplers, screens, collecting-belt, railway-wagons, and bunker; two sweep-ups are also provided at the ground-level. The coal-dust is drawn off the "collector" into colliery tubs, and deposited by means of a creeper and a hoist into the bunkers of the dust-fuel boiler.

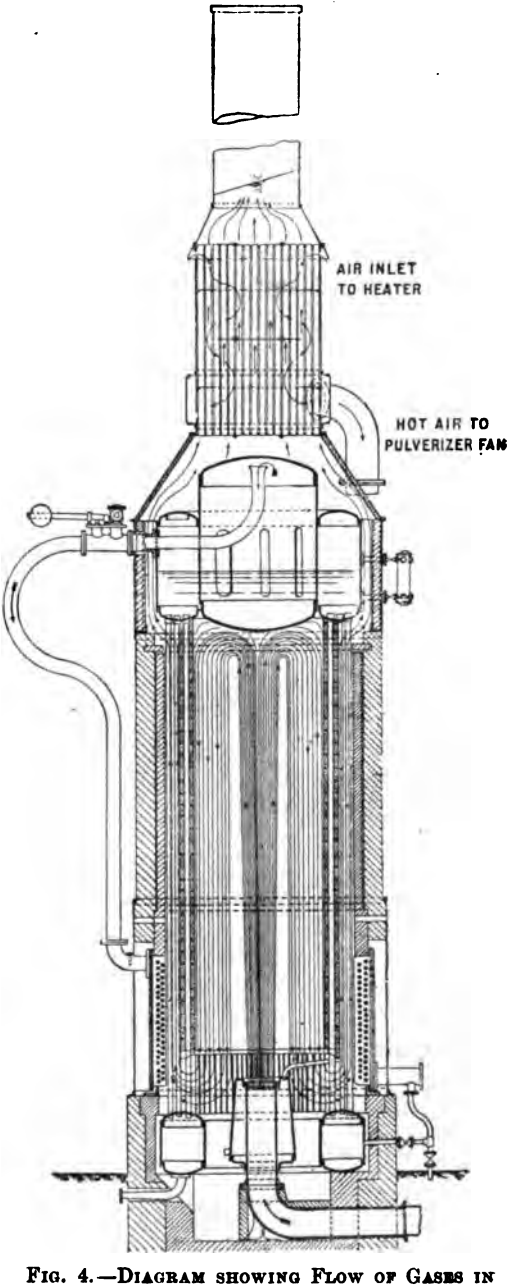


FIG. 4.—DIAGRAM SHOWING FLOW OF GASES IN THE BETTINGTON BOILER.

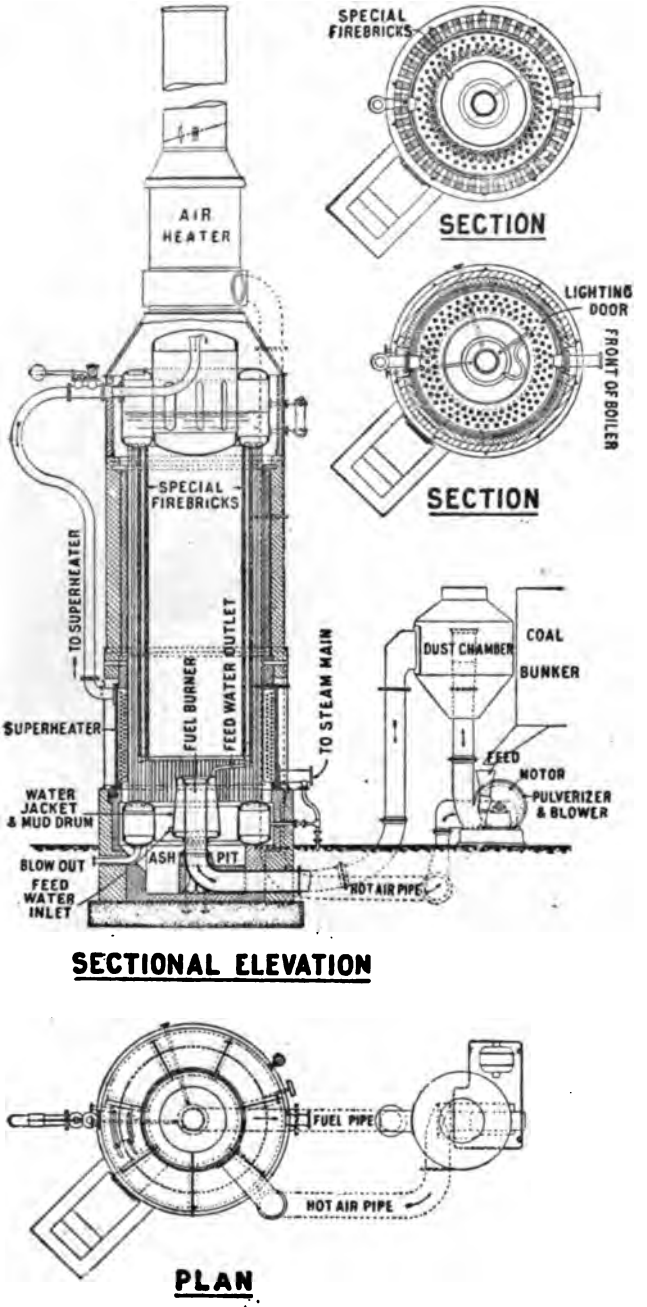


FIG. 5.—SECTIONAL ELEVATION, CROSS-SECTIONS, AND PLAN OF BETTINGTON BOILER.

The Bettington Boiler.—This boiler is the outcome of many experiments made in America and South Africa by Mr. Bettington, and was designed primarily for burning low-grade fuels in those countries. The boiler is constructed for a working pressure of 160 pounds per square inch, and to superheat the steam by 110° Fahr. It will be seen from the illustrations (Figs. 4, 5, 6, and 7) that it is of the vertical multitubular type, consisting of a bottom and a top header, supported by three rows of tubes 3¼ inches in diameter, and so designed that expansion can take place without straining the boiler, the air-heater and chimney being supported on independent brickwork.

FIG. 6.—SHOWING FIRST STAGE OF CONSTRUCTION OF BETTINGTON BOILER.

The boiler is fired by a central tuyère, or gas-jet, 14 inches in diameter. This tuyère is water-jacketed, and cooled by the feed-water which is led by a special tube from the jacket to the top-header. The steam passes out from this top-header in a saturated state, and is led down to the superheater. The superheater is made up of a series of horizontal tubes which pass round the boiler, between the brickwork and the outer row of vertical tubes, the steam finally leaving the boiler at this level.

The boiler-fittings are as follows:—Two safety-valves, two Klinger water-gauges, two fusible plugs, two blow-off cocks, a low-water alarm, and an arrangement for flooding the superheater when starting. Manholes are fitted in the headers, and are so arranged that any one of the vertical tubes can be withdrawn without disturbing the others. These headers are sufficiently large to admit a man, and, as all the tubes are straight, each one may be visibly inspected throughout its entire length from the headers, without the removal of any caps. The inner row of tubes is covered with a specially shaped firebrick, and is in this manner protected from the flames, thus forming a combustion-chamber closed at its upper end.

FIG. 7.—BETTINGTON BOILER COMPLETED.

The fuel is led from the bunker, by means of a worm, into an electrically-driven pulverizer (Fig. 8), running at 1,500 revolutions per minute. The pulverizer consists of a number of manganese-steel blades, or beaters, revolving in a casing lined with steel liners. These beaters grind up the coarser particles of of coal, and constitute a fan which produces the necessary draught for forcing the dust into the furnace. Two slides are provided on each side of the casing, for varying the amount of air required

for combustion. Air is also drawn from the air-heater situated in the chimney-stack, the coal-feed being regulated by a variable speed device fitted on the worm-shaft. The coal-dust is then forced, together with a correct proportion of air, into a separator; the fine dust is blown through a gauze, the larger particles falling down to be repulverized.

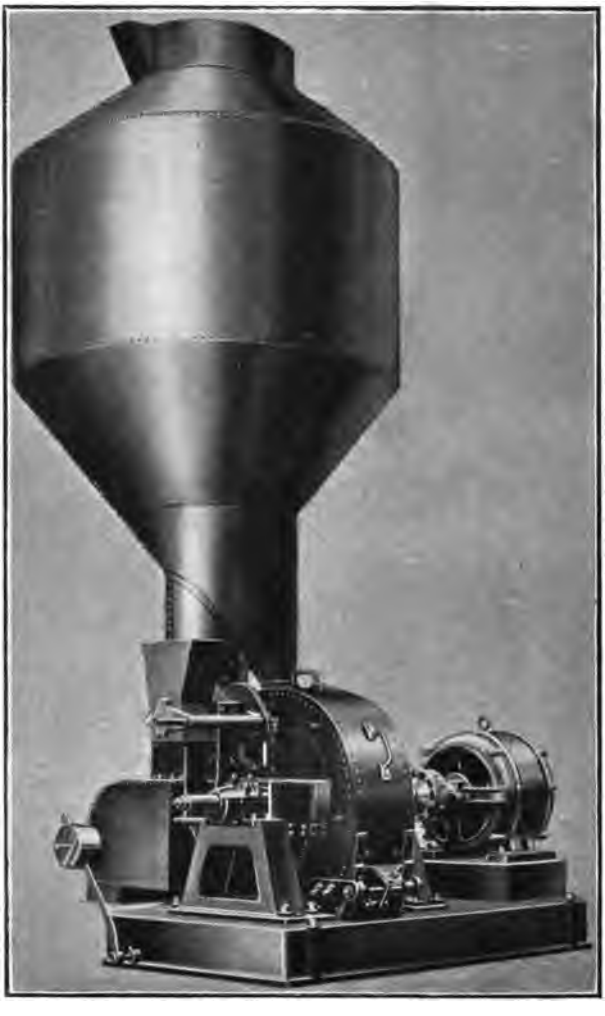


FIG. 8.—ELECTRICALLY-DRIVEN PULVERIZER AND BLOWER.

It will be seen from the foregoing description that a steady stream of combustible material is forced into the furnace. This mixture of coal-dust and air, which practically constitutes a coarse gas, and should be theoretically in the proportion of 1 to 11½ by weight, enters the furnace through the water-cooled nozzle, and is here ignited.

It is found that, owing to friction and expansion, the air soon loses its initial velocity, but that the particles of coal-dust continue in their upward direction until they strike the top of

the furnace; where, owing to gravity, and to the fact that they are cooled by striking the under side of the top header, they descend, and, in exceeding the velocity of the air, become completely oxidized. The advantage of vertical as opposed to horizontal stream-lines is that, in the former, momentum and gravity act together, whilst, in the latter, they act at right-angles to one another. The size of the dust-particles is therefore limited to that which can be completely consumed in the time occupied on the journey up and down the furnace; and it has been found in practice that this furnace will consume coarser particles of coal than any other which has hitherto been constructed for burning pulverized fuel.

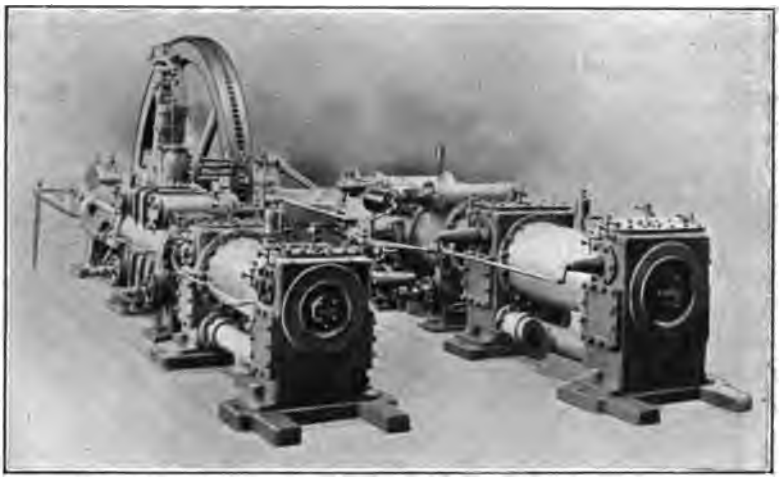


FIG. 9.—COMPOUND STEAM TWO-STAGE AIR-COMPRESSOR.

The ash in the fuel, during its passage through the furnace, is converted into a liquid spray, the greater portion of which strikes the brickwork, and fills up the crevices. In lining the furnace, therefore, it is only necessary to build up the bricks by placing them one upon another, no fire-clay being needed; in fact, after a few weeks' working the interior will present a glazed appearance, forming one solid mass, and thus protecting the first row of tubes from the flames.

The internal face of the brickwork always remains in a semi-molten state, forming a reserve of radiant heat, ready to be transformed into steam at a moment's notice, should a sudden

demand be put upon the plant. It is found to be quite unnecessary to provide a large steam-space, the top header being only 6 feet in height by 10 feet in diameter.

The fire is lighted by placing a torch on the edge of the fuel-nozzle, and ignition will take place on starting the pulverizer. Steam can be raised and the boiler put into service, without undue strain, in a space of 30 minutes. The fire is put out by switching off the motor, and after short stoppages can be relighted automatically by the incandescent brickwork.

Two pulverizers are provided, the second being driven by a steam-engine running at 1,000 revolutions per minute. Either pulverizer can be put into use without disturbing the fire, and the pulverizers can be run together in case of a sudden overload.

The boiler supplies steam for driving an air-compressor (Fig. 9) of 630 indicated-horsepower, and steam is also supplied through a reducing-valve to various colliery-engines situated about 300 feet from the boiler.

The writer has, in conjunction with the makers, taken evaporative and consumption tests of the boiler and air-compressor, and gives in Tables I. and II. some of the figures that were obtained:—

TABLE I.—TEST ON A NO. 2 BETTINGTON DUST-FUEL BOILER.

Heating surface: water, 2,308; steam, 507; total, 2,815, square feet.	
Duration of test	3 hrs. 56 min.
Total coal used, in pounds	4,256.
Total coal used per hour, in pounds	1,078.
Total water evaporated, in pounds	33,490.
Total water evaporated per hour, in pounds	8,550·8.
Feed-water temperature entering tuyère	143·6° Fahr.
Steam-pressure, in pounds per square inch	148·2.
Superheat	159·° Fahr.
Temperature of air entering air-heater	52·4° Fahr.
Do. leaving do.	238·7 ,,
Temperature of flue-gases leaving boiler	543·4 ,,
Do. do. air-heater	447·8 ,,
Do. fuel-mixture entering furnace	113·2 ,,
Equivalent pounds of water evaporated and superheated per hour from and at 212° Fahr.	10,295·1.
Equivalent pounds of water evaporated per square foot of heating surface	3·66.
Power used by pulverizer as percentage of power developed	2·0.
Analysis of coal used:	
Ash, per cent.	16·98.
Volatile matter, per cent.	27·64.
Fixed carbon, per cent.	55·38.
Water evaporated per pound of dry coal from and at 212° Fahr.	9·60.
Calorific value of coal (dry), in British thermal units	12,120.
Do. do. expressed as pounds of water evaporated from and at 212° Fahr.	12·56.
Thermal efficiency of boiler as based on coal, per cent.	76·43.

TABLE II.—TEST ON A RIEDLER CROSS COMPOUND TWO-STAGE AIR-COMPRESSOR.

Mean revolutions of engine per minute		73·2.
Steam-pressure above stop-valve, in pounds per square inch		147.
Steam-temperature		497° Fahr.
Vacuum in exhaust-pipe, in inches		24·4
Horsepower consumed by condenser		8.
Air-pressure in receiver, in pounds per square inch ...		71.
Indicated horsepower from steam-cylinders		613.
Do. do. air-cylinders		560.
Mechanical efficiency of air-compressor, per cent. ...		91·4
Actual steam-consumption of compressor per hour, in pounds	8,401	
Deduction for feed-pump and loss in steam-range	149	
		8,550.
Actual steam-consumption per indicated horsepower-hour, in pounds		13·7.
Volume of free air delivered, in cubic feet per minute ...		4,020.
Volumetric efficiency, per cent.		97·5.

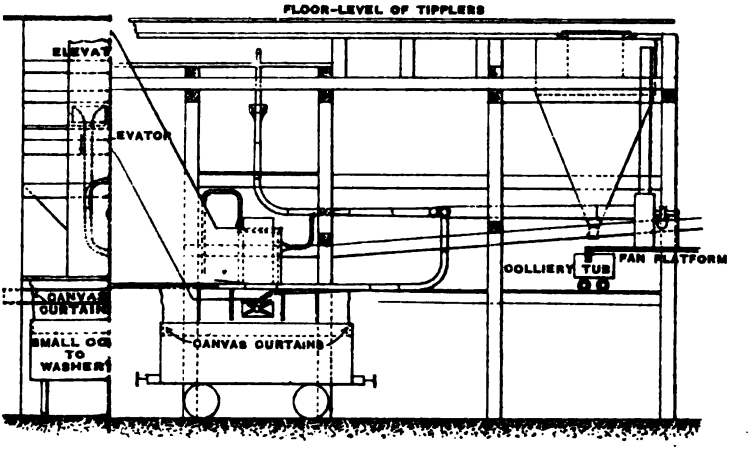
The above tests were carried out after the plant had worked for 6 months on full load, and were, as will be noted, of short duration; but, owing to the fact that there is no fire-grate, and also that the water-space is small, very accurate results can be obtained.

The thermal efficiency of the boiler, naturally, is dependent on the figure given for the calorific value of the coal, which the writer has always found a difficult matter to obtain with any degree of accuracy, but the figure given is a good average. As the boiler, when supplying this compressor with steam, was working at only 85 per cent. of its full normal capacity, the test was not taken under the best conditions. Its normal output in pounds of steam per hour from and at 212° Fahr. is 12,000 with one pulverizer, and 20,000 pounds have been obtained when running the two pulverizers together.

It is only necessary to clean out the ash-pit once every 48 hours. Owing to the rapid water-circulation, the tubes keep clean, any scale or mud being deposited in the bottom header.

The fuel at present being used is screened through mesh-plates the perforations of which are an eighth of an inch in diameter; and it is estimated that 30 tons of coal-dust per week will be added from the collection-plant when in full operation. The boiler is at present consuming about 50 tons of coal per week, and it is found that the pulverizer-blades, which cost £2 for a set of sixteen, will run for 1,000 hours. The liners, which cost £4 for a set of twenty-six, will run from 2,000 to 2,500 hours.

FIG. 3.—SIDE ELEVATION.



SCREEN-DUST RECOVERY PLANT
D COLLIERY, NEAR MANCHESTER.

This boiler therefore compares very favourably in upkeep with any other boiler fitted with a mechanical stoker. It is found to be practically smokeless in operation, as only a film of grey dust is emitted from the stack.

The initial cost of the boiler is not heavy, when it is understood that neither economizer nor chimney-stack is needed; and the writer is of the opinion that, in the larger sizes, it would not be more expensive in first-cost than other makes of water-tube boilers. It was very pleasing to find how readily the men, who had never before seen a water-tube boiler, adapted themselves to the working of the plant.

During the 19 months that the boiler has been in use, working for 120 hours each week, only once has there been any trouble, owing to a slight leakage of water at the fuel-nozzle, which put the fire out. This part has been welded up, and is quite satisfactory. The makers are now in all cases supplying a welded fuel-nozzle, the use of rivets being thereby obviated. The brickwork is in good condition, and the tubes are as clean as when they were erected.

Conclusion.—It will be seen from this paper that it is possible to consume efficiently coal-dust collected at a colliery, a fuel that has hitherto been considered as waste-material and therefore received little attention, and one which has in many cases found its way to the colliery refuse-heap.

The advantages of this type of boiler may be summed up as follows:—(1) High thermal efficiency, (2) smokeless combustion, (3) quick steaming, (4) flexibility in output, (5) small ground-space required, (6) no banked fires, (7) low radiation losses, and (8) the use of low-grade fuels. The writer is certain that, with the adoption of similar plants at collieries, greater attention would be given by colliery engineers to the collection of coal-dust, thereby converting to a useful purpose a fuel which is at present a source of constant danger and anxiety to all who are engaged in coal-mining.

Mr. Hart-Davis, after reading the paper, exhibited a number of lantern-slides illustrating the plant, etc., described.

Mr. Leonard R. Fletcher (Atherton) moved that the thanks of the Society be accorded to Mr. Hart-Davis for his interesting paper.

Mr. WILLIAM WATTS (Wilmslow) had great pleasure in seconding the motion.

Mr. FRANK HENRY WHYSALL (Manchester) said that he had been much interested in Mr. Hart-Davis's description of the dust-fuel boiler, and was very grateful to him for the paper. It certainly showed marked advance in this particular type of boiler. The nearest approach to a powder-fuel furnace of which he had had experience was in connexion with a boiler fired with powdered fuel and mechanically stoked, sprinkler-stokers being used. He supported Mr. Hart-Davis in the conclusion at which he had arrived. In previous experiments the dust went right through the boiler, and gave considerable trouble because of the fine dust that was deposited on the roofs of adjacent buildings; in fact, it was like a fine rain all round the works when these boilers were working. He thought that the problem of the consumption of low-grade fuels, especially fine fuels, was at one time on the point of being solved by the gas type (the Siemens type) of furnace, such as was generally adopted now in industrial processes, particularly metallurgical. He had looked up a few particulars of early operations in connexion with powdered-fuel furnaces in boilers, as he thought that they might be of interest to Mr. Hart-Davis and to the members generally. As far back as 1857 patents were taken out for this method of burning fuel by a Mr. Bourne, and in the *Journal of the Iron and Steel Institute** something was said as to the results obtained by Mr. T. R. Crampton in revolving furnaces using powdered fuel, but they were not anything like those shown in the tests described by Mr. Hart-Davis. As to the temperature of the flue-gases leaving the boiler, he noticed that Mr. Hart-Davis gave it at 543·4° Fahr., and suggested that this temperature was too high to waste, and would be better absorbed in some form of economizer for heating the feed-water. With regard to the bricks for the furnace-lining not requiring any cement, at an ironworks where he had had some experience slag was at one time used to help that process of brick lining in puddling-furnaces. He was sure that the author of the paper deserved to be congratulated on the important progress in the use of powdered fuel for boilers, and he thanked the Society for the opportunity of being at the meeting.

* 1873, vol. i., page 91.

Mr. WILLIAM SPEIGHT (Atherton) said that he would like to ask Mr. Hart-Davis one or two questions. Was the dust-collecting plant already in operation? If so, what was the percentage of dust that was sent out with the air, or could they keep it all in the cyclone collector? He had had some experience of collecting dust, and his trouble had been to turn out the air in something like a clean condition. Very little difficulty had been experienced in collecting the dust and preventing it from going down the shaft; but the great trouble had been to prevent any dust from being turned out into the air. The plant was probably badly situated, being near to a number of houses and a school, and the nuisance inspector had warned them that they would have to stop the emission of so much dust. To meet the difficulty, they had tried spraying with steam-jets. He would like to know whether the difficulty could be overcome under such conditions as theirs, and the dust still collected dry.

The Bettington boiler seemed to be very efficient; in fact, the whole plant appeared to be more efficient than any that he had yet met with. Probably the boiler had a great deal to do with the success of the experiment. The results described by Mr. Hart-Davis of the air-compressor were better than any that he and his colleagues had been able to get, and certainly appeared to be very satisfactory. With regard to the dust and the apparatus for collecting dust, it struck him that the size of the plant seemed very small for the number of screens in use. He had a much larger motor and fan in use on a similar number of screens, and yet, when the wind was blowing in one particular direction, it seemed to fill the screen-chamber at the aperture or outlet for coal, and dust was blown out at the tipplers and went down the pit.

He had been much interested in the paper; it had been quite a revelation, showing what could be done with boilers fired with waste-fuel. At the same time, it did not appear to him to be a system that could be generally adopted. At the colliery with which he was connected they had to use a good deal of waste stuff that was unsaleable, such as wet slurry from the washery, bone, and pickings from the screen-room, which did not appear suitable for use in the Bettington boiler, and yet could not be put on the dirt-heap.

Mr. W. Bolton Shaw (Manchester) offered his congratulations to Mr. Hart-Davis on his paper and the excellent results that he had obtained with the boiler. He assumed that the fuel used in connexion with the test of the boiler was the ordinary colliery fuel which they might be expected to get every day. One of the difficulties met with, when a large electrical installation had been put down at a colliery and was running well loaded, was to keep up steam at a steady pressure, so as to maintain satisfactory running and supply. It was almost an absolute necessity that the steam should be kept within fairly narrow limits of pressure. The old-fashioned method of the boiler-fireman putting on a lot of coal and forcing up the fires to get the steam-pressure to blowing-off point, and then sitting down to wait until it got down again, would not do for an up-to-date plant. A colliery naturally expected to get rid in its own boilers of all its unsaleable fuel, and this often meant a great variety of size and quality, including dust, pickings, large lumps of inferior coal, and possibly washery settlings; and it was a difficult matter, even for good stokers, when the material was thrown into the bunkers anyhow, to keep steam at a regular pressure. In order to do so, the firing must be erratic, very heavy at times and comparatively easy at other times, depending on whether they came across a quantity of good or bad coal. One way of getting over that difficulty would be to collect the coal that was to go into the bunkers—a full week's supply—and devise some means of mixing it so that the size and quality of the supply would be more uniform. That seemed impracticable, or at any rate difficult, to carry out on a large scale. Another possible way of doing it was the method adopted in the dust-fuel boiler, which appeared to be so flexible as regards the rate at which it could be fired that they could follow up any great change in the quality of the fuel supplied, and the difficulty of the varying size of the coal was got over by grinding. The Bettington boiler seemed to him, therefore, to have made a considerable advance in the problem of steady steam raising at a colliery. The figure which Mr. Hart-Davis had given for the power absorbed by the pulverizer was 2 per cent. of the power developed, and he should like to know whether the fuel put into the pulverizer was already all dust, as taken from the screens, or whether it included any round coal, or coal of the size of nuts or cobbles. That, of course, was an important

matter, because if the grinding of the large coal into dust was going to absorb a great deal of power, a considerable part of the advantage was lost. That seemed to have been one of the difficulties in previous coal-dust arrangements for firing. Another point on which it would be interesting to have some information was, what happened in the case of coal-dust containing a considerable amount of stone-dust and dirt? How did that affect the firing, and was there any possibility, with very dirty dust, of the fire actually going out? Mr. Hart-Davis referred to the slag which was formed from the ash becoming coated on to the surface of the fire-brick lining. In one of the diagrams of the boiler the flames appeared to go up the central tube, down the outside of it, and then up again. On the third traverse it came into contact with the boiler-tubes, and the temperature of the gases would still be high, as he (Mr. Bolton Shaw) assumed that in going down the outside of the central tube the gases would not lose much heat, because the inner row of tubes was protected by firebrick. Was there any possibility that on the third traverse some slag might be present which would coat the tubes and so spoil their heating efficiency? A further point on which some information would be interesting was the size of the boiler. If the principal dimensions of the boiler were given, it would enable them to compare it with other types. He understood that it had been proposed to apply the boiler to the roasting of finely-divided ores containing sulphur, the heat obtained from the combustion being used for raising steam. He should like to know whether Mr. Hart-Davis could give any information on this point, as it seemed to be of some interest.

Mr. Joseph Dickinson (Manchester) said that the process described by Mr. Hart-Davis had apparently been thought of long ago, and experiments made. One such was described by Mr. Thomas Russell Crampton, of 13, Great George Street, Westminster, in 1869, for which he had a patent, and details were given in the Report of the Coal Commission of 1871. It was described as suitable for ordinary works, but not for blast-furnace smelting. The fuel was reduced to an impalpable powder, crushed by an ordinary millstone, at a cost of from 6d. to 1s. 6d. per ton. This crushed fuel was dropped into the furnace, where it came into contact with a blast of air, in

regulated proportions, and became consumed in a little more time than gas. Particles of coal larger than the impalpable powder required time for their consumption according to their size. The cost was stated at about a third, time was saved, and there was no smoke. It seemed to him that if only a small proportion of the advantages claimed for this process were available, it was surprising that it had not made greater progress.

Capt. Henry V. Hart-Davis (Worsley) congratulated Mr. Hugh V. Hart-Davis on his paper. It dealt with matters in which they at the Bridgewater Collieries were greatly interested. They had been engaged for some time in the study of the Bettington boiler, and in October, 1909, had sent some of their men to see the boiler at the works of the makers, where they had witnessed certain fuel-tests. Bridgewater coal-dust was tried, and the following were the principal observations taken:—The test commenced at 11·30 a.m. and lasted 1 hour; 1,200 pounds of coal-dust were burnt, and 8,075 pounds of water were evaporated (equal to 6·73 pounds of water evaporated per pound of coal). The boiler-pressure during the test was from 150 to 160 pounds per square inch; the carbon dioxide was 14 per cent.; and the blow-off pressure was 160 pounds per square inch. The boiler, it was stated, was producing about 1,200 horsepower. It was necessary first to pulverize the fuel, and then to pass it through a carburettor, where it was mixed with a proper proportion of air. A small fan was fixed between the carburettor and the boiler in order to send the air and fuel into the combustion-chamber, where complete combustion took place with the right proportion of fuel and air admitted. The construction of the boiler was very good. Although the boiler had not been at work long enough to indicate any idea as to its life, no leakage of tubes or other parts had been experienced during the 7 months that it had been in use. The commonest of fuel could be burnt by the Bettington boiler, provided that it was first pulverized, and Mr. James Robinson (one of the representatives of the Bridgewater Collieries who had witnessed the tests) had no doubt that where the boiler could be applied it would prove a great saving over any other boiler on the market. A point of special interest to him was as to how far it could be used for winding purposes. He assumed that in the

installation at Outwood the boiler was coupled to a compressor. He would like to know Mr. Hart-Davis's views with regard to an ordinary winding-engine—whether the boiler was suitable for attachment to such an engine. It seemed to him that where there was only an intermittent steam use, it might not be wise to use this boiler only; but, if a constant pressure were required, he would recommend that it should be coupled up with some ordinary Lancashire horizontal boilers. A Bettington boiler had not yet been erected at the Bridgewater Collieries, as they were anxious to learn more about it.

Mr. E. E. Baker (Liverpool) supposed that, in arriving at the brake-horsepower available from the engine, all the auxiliaries were taken into account, although this point was not very clearly stated in the paper. There was the power used by the pulverizer, which amounted to 11 horsepower; the condenser, 8 horsepower; the boiler-feed (which was not mentioned by Mr. Hart-Davis), about 17 horsepower; and then there was the collection of the dust, about 20 horsepower. That would amount to about 50 brake-horsepower. The mechanical efficiency of the engine did not appear to be given, but if that were 90 per cent., there was about 500 brake-horsepower available from the engine, and that was evidently got for a consumption of about half a ton of fuel per hour. If the writer of the paper would give the members the correct figures, they would be of assistance in getting at the actual results.

Mr. Alfred J. Tonge (Hulton Collieries) said that he had had the pleasure of seeing the boiler at work at the works of the makers, but he was at that time more interested in the engine for which the steam was generated than in the boiler. He remembered that whether much steam or little steam was required the boiler could respond fairly well—a fact which he thought would partly answer the question put by Capt. Henry Hart-Davis in regard to the capability of the boiler in generating steam for winding purposes. What impressed him was the efficiency of the boiler, which gave over 9 pounds of steam per pound of coal; and it was apparently common coal also. He had had figures before him showing that dust could be brought up from the deepest mines much better by suction than by winding it in the form of coal. It had even been suggested that coal should be crushed

in the mine and brought up in the form of dust rather than in the form of round coal. If that were so—and it was a very able man who had made the suggestion—such a boiler as the Bettington boiler would be brought speedily into use. The best results could only be got out of coal by obtaining the most intimate mixture of coal and air, and that could only be achieved by pulverizing the coal as finely as possible. He would not be surprised if in the future dust were burned in boilers from the standpoint of economy, and not simply because they had dust on hand.

Mr. CHARLES PILKINGTON (Clifton and Kersley Collieries) said that, with regard to the waste-fuel that came from the mines, there was the dirt and intergrown coal which was picked out of the coal to be considered. It would hardly pay anyone to grind that into dust, as it often contained pieces of pyrites and other hard substances. It seemed to him that different kinds of waste-fuel would have to be dealt with in different kinds of boilers. As Capt. Henry Hart-Davis had rather suggested, a combination of one or two dust-fuel boilers and a range of Lancashire boilers might be the best arrangement.

Mr. J. D. PATON (Manchester) said that, as the ash percentage in the coal was 16, as the total coal burned per 48 hours was equal approximately to 24 tons, and as it was stated that it was necessary to clear the ash-pit once in 48 hours, the dimensions of the ash-pit seemed rather small for this quantity of ash.

Mr. HUGH V. HART-DAVIS (Pendleton), in replying to the discussion, referred to Mr. Whysall's opinion that the temperature of the flue-gases leaving the boiler was rather high. He (the speaker) quite admitted that this figure could be improved upon with the addition of an economizer. This had been adopted on a boiler of the type in question at Johannesburg, and in that case, owing to the low temperature of the gases, there was a difficulty with the draught, and the pulverizer had to be speeded up in order to get the required flow of gas up the stack. He was of the same opinion as Mr. Whysall, that low-grade fuels could only be efficiently consumed in a pulverized state.

In reply to Mr. Speight, he did not think it possible to collect more than 60 to 70 per cent. of the dust on the screens by means of

induced draught. Probably a great deal of the horsepower that Mr. Speight had mentioned was due to the design of the air-pipes: 12 horsepower would easily do the work of the collecting plant described in the paper. He would suggest to Mr. Speight that, if he was troubled with the dust that came away from the collector, he should instal one of these boilers at his colliery, and blow the dust and air straight into the furnace of the boiler; he would then, if he had sufficient dust, save the cost and wear and tear of a pulverizer.

Mr. Speight had remarked on the high efficiency of the air-compressing plant. He (the speaker) knew that Mr. Speight had two compressors of the same size as the one at Outwood, but the figures given were better than Mr. Speight's because he had a superheat of 150° Fahr., which in itself was saving 15 per cent., and also a higher steam-pressure and a good vacuum. With regard to the point about slurry, one of the objects of the paper was to show that it was possible to consume fine coal in a dry state, and therefore the amount of slurry at a washery would be reduced to a minimum. As to pickings and chippings, these had a greater commercial value than either dust or slurry.

He agreed with Mr. Bolton Shaw that the steady steaming and flexibility of the boiler was especially favourable for power-station work; for if a sudden overload came on, as frequently happened at power-stations, the second pulverizer could be put into operation, and an overload on the boiler of 80 to 100 per cent. could be obtained in this manner.

With regard to the power taken by the pulverizer, the increase in the horsepower was not perceptible when pulverizing large coal; it was the pulverizing to the last degree of fineness that took the greater portion of the power. Coal with as low a calorific value as 9,600 British thermal units has been consumed in this boiler.

Mr. Bolton Shaw had asked whether the ash and slag collected on the tubes. The bulk of the slag was deposited on the brick-work in the downward journey of the gases; some dust, of course, was carried up on the third journey; but the temperature of the gases was at this point lower, and the ash did not adhere to the tubes—it fell down in a fine state into the ash-pit.

The diameter of the boiler was 10½ feet, and the vertical centres of the two headers about 25 feet.

Mr. Joseph Dickinson had mentioned that the burning of coal-dust had been considered in 1869, and gave the cost of crushing the coal as from 6d. to 1s. 6d. per ton. He (the speaker) had calculated the cost of the wear and tear of the pulverizer at Outwood, and found that it did not exceed 2d. per ton of coal consumed.

He was obliged to Capt. Henry Hart-Davis for the information as to the results of the tests that he had made in 1909. He thought they had got better results at Outwood because the dust was dry.

As to the question of utilizing dust-fuel boilers in connexion with winding-engines, at most collieries the dust that could be used in these boilers did not exceed 2 per cent. of the total output, and at the present time many collieries were consuming from 8 to 10 per cent. of their output; therefore, the Bettington boiler could only be used in the proportion of 1 to 5. The dust-fuel boiler could then be kept at its full operation, the other boilers being, as it were, receivers for the winding-engines.

In answer to Mr. Baker, it would be seen from Table II. that there was a deduction of 149 pounds of steam for the feed-pump and loss in steam-range.

He quite agreed with Mr. Pilkington that the large coal should be kept for use in other boilers, and should not be pulverized. They had tried to dry the slurry from the washery, and had no difficulty in burning it, the only difficulty being that of getting it into the pulverizer.

Mr. Paton had mentioned the fact that the boiler was only cleaned out once in 48 hours. This boiler consumed, approximately, half a ton of coal per hour, so that with a fuel containing 20 per cent. of ash there was about 4½ tons deposited in 48 hours. The ash-pit was quite capable of holding that amount.

It was true that with the Outwood boiler a certain amount of dust was emitted from the stack. It would be better, therefore, when installing a boiler of this type, to bring the flue-gases down through an economizer, so that this ash would have more chance of being deposited.

In conclusion, he thanked the members present for their attention and for the discussion given to his paper. He hoped that it would, if only to a small extent, help the mining engineer in some of the difficulties which beset his profession.

THE MANCHESTER GEOLOGICAL AND MINING SOCIETY.

SPECIAL GENERAL MEETING,
HELD AT THE UNIVERSITY, MANCHESTER,
FEBRUARY 27TH, 1912.

THE PRESIDENT, MR. GEORGE B. HARRISON, IN THE CHAIR.

The following paper on "The Prevention of Explosions in Mines" was read by Dr. John Harger:—

THE PREVENTION OF EXPLOSIONS IN MINES.

By JOHN HARGER. M.Sc. (Victoria), Ph.D. (Heidelberg).

The writer's object is to bring before the notice of the members, for consideration and criticism, a method of preventing dust explosions, fire-damp explosions, and fires in mines and elsewhere. It is a simple method, and so easily applied that he ventures to think that it will be taken up ere long, tested on a large scale, and finally adopted at all coal-mines, because all mines are liable to fire-damp explosions, and still more liable to accidental fires in the roads.

Before considering the question of explosions, it is necessary to state a few elementary facts respecting combustion and respiration. A candle-flame burning in air in a closed space gives off carbon dioxide and water, and will burn until the amount of oxygen left is from 17 to 17½ per cent., and will then go out. Petroleum oil, benzene, ligroin, and petroleum ether, when burnt in a lamp with a wick, have each a definite and different composition of atmosphere at which they go out. These solid and liquid combustibles all go out while there is still, one would think, plenty of oxygen for them to continue burning. The writer finds that if measures are taken to absorb the carbon dioxide as it is formed, there is a little difference, but not much—the percentage of oxygen left is a little less in most cases. With some gases, such as coal-gas, acetylene, hydrogen, etc., the percentage of oxygen left when the flames go out is not very great, as may be seen from Table I. Fortunately for miners, methane is very sensitive to deficiency of oxygen.

Table I.—Percentage of Oxygen left in Air at which different Flames go out.

	Per cent.	
Soft candle	16·9—17	
Petroleum	16·9	
Ligroin (B.P. 90°-120°)	16·9	
Petroleum ether (B.P. 19°-33°)	15·5	
Benzene	16·4	
Hydrogen	7·5	
Acetylene	9·5	Marked decrease of illuminating power at 11·2 per cent. Flame leaves jet at 11·2 per cent.
Liverpool coal-gas	11·5	
Methane ... ... (about)	17·5	

The case of the acetylene flame is rather special and interesting. It appears, as it were, to cling to life. Towards the end it separates from the material of the jet, and as a hollow double cone of flame wanders about, apparently seeking more congenial surroundings. Methane behaves in the same manner, but goes out very soon after leaving the jet. The writer will not stop here to discuss why the flames go out at these particular points; it is sufficient for the present purpose to know that there is a minimum percentage of oxygen required by each of these combustibles to enable them to burn, and in the case of liquids and solids, and methane gas, this is not very small.

The average person knows that atmospheric air contains about 21 per cent. of oxygen and 79 per cent. of nitrogen (with other inert gases), mixed with a trace of carbon dioxide and varying amounts of water-vapour. He has been told that air which will not support the combustion of a candle is not fit to breathe, and believes it. Physiologists and some mining people of course know better, but most of the latter think that they have had a narrow escape if forced to travel a mile or so of roadway, the air in which will not support the combustion of an oil-lamp.

When ordinary air is breathed, an examination of the exhaled air shows that only a small amount of the oxygen has been used. A test showed the respired air, after removing water vapour, to be 3½ to 4 per cent. of carbon dioxide, 17 to 16½ per cent. of oxygen, and 79½ per cent. of nitrogen.

As so little of the total amount of oxygen in the air is used in breathing, it may well be asked: Is it necessary to have so much more than we use? The answer is: No; it is not.

No one would know that he was breathing anything different or unusual if a supply of 17½ per cent. of oxygen with 82½ per cent. of nitrogen were put into a room to replace the ordinary air. It would make no difference at all. As long as there is the minimum amount of oxygen necessary to re-form the normal amount of oxy-hæmoglobin from the venous blood with ease, it is all that is needed; any more acts as an indifferent gas, or almost so. The fact is, the lungs are able to take the amount of oxygen required just as easily from an atmosphere containing 17½ per cent. of oxygen as from one containing 21 per cent. The reason for the air being expelled from the lungs when it has still 16½ to 17 per cent. of oxygen is as follows:—

The depth and frequency of breathing are unconsciously so regulated as to keep the proportion of carbon dioxide in the air, in contact with the lungs, constant at about 5½ per cent., so that the arterial blood leaving the lungs is saturated with air of about that percentage. The slightest increase of carbon dioxide in the arterial blood is sufficient to excite to increased activity the nerve-centre which regulates the breathing. When double the amount of oxygen is used, this is not taken from the same volume of air (by reducing it to, say, 12 per cent. of oxygen instead of 16½ to 17 per cent., as this would mean having about 10 per cent. of carbon dioxide in the lungs), but by breathing twice the quantity of air.

In the case of combustion, it is the percentage of oxygen that matters, but in the case of respiration, it is the actual quantity—the weight of oxygen in a given volume*—that counts.

The oxygen percentage at sea-level can be reduced to 14 before any shortage is noticed, and then it is only slightly noticeable when doing hard work. A climber does not notice any lack of oxygen until he reaches an altitude of 9,000 feet above sea-level, or thereabouts, at which the oxygen tension is 14 per cent. of an atmosphere. When the oxygen at sea-level is reduced to 12 per cent., or with ordinary air at 14,000 feet, the shortage is distinctly noticeable even with the exertion of ordinary walking on the level. Below 10 per cent. it is becoming dangerous, and at from 7½ to 8 per cent. one cannot exist for more than a short time. Death ensues at 7½ per cent. in the same way as a candle is extinguished at 17 per cent.

An atmosphere containing 14 per cent. of oxygen at sea-level corresponds to one with a much smaller percentage in a mine 3,000 feet deep. Taking the other extreme, 75 per cent. of oxygen acts as a poison, and pure oxygen, especially under pressure, acts quickly, producing violent inflammation of the lungs, convulsions, and death.

Most people have delusions concerning carbon dioxide; but physiologists assert that a small percentage of that gas in the air is immaterial: 2 per cent. in the air only makes one breathe deeper, which is a good thing—occasionally, at any rate. The presence

* A cubic foot of air with an oxygen percentage of 17½ contains at sea-level almost exactly the same weight of oxygen as a cubic foot of air with an oxygen percentage of 21 at an altitude of 5,000 feet. A lamp will not burn in the first, but will burn quite well in the second. For respiration the two act exactly alike.

of 1 per cent. of carbon dioxide increases the depth of breathing by a sixth, which is not noticeable, and this certainly has no bad effect in ordinary air, or in air containing 17½ per cent. of oxygen. It is not until from 6 to 8 per cent. of carbon dioxide in the air is reached that toxic symptoms appear, but as much as 25 per cent. is needed to cause actual danger to life.

It will no doubt be said that if the foregoing be true—that is, the condition respecting the smaller oxygen percentage and the higher percentage of carbon dioxide, what about the difficulty of working in a bad atmosphere, such as a stuffy room, or, for example, in some mines? This brings one to the last important factor in respiration—the water-vapour. Water-vapour is of much more importance in respiration than was thought to be the case some years ago. It is the presence of this vapour from which one wishes to get away in a hot stuffy room or mine. It is not noticed much below 70° Fahr. wet bulb; but above that temperature it is uncomfortable and stuffy. At a wet-bulb temperature of 80° Fahr., the amount of continuous work which a man is capable of doing without serious rise of bodily temperature rapidly falls off, and becomes practically *nil* at 90° Fahr. (wet bulb), even though, as in hot mines, very little clothing be worn. There are many other interesting points on respiration, but the writer thinks that the foregoing are all that need be mentioned for the present purpose.

Dr. J. S. Haldane has demonstrated the 5½ per cent. carbon-dioxide constant;* also the fact (in his work done with others in America last year at an altitude of 14,000 feet) that with only 12 per cent. of oxygen a marked deficiency of oxygen is noticed even with moderate exertion. Dr. Haldane stated in a letter to the writer that a reduction of oxygen to 17½ or 18 per cent. is immaterial for respiration, and he adds the interesting information that the oxygen-tension in the lungs in a mine, even when a flame goes out, is greater than in ordinary air at sea-level.

Dr. Leonard Hill, another great authority on respiration, whose word should carry conviction, as he has been engaged on research work on this subject for 15 years, makes the following statement in a letter to the writer:—

* *Journal of Physiology*, 1905, vol. xxxii., pages 225 and 486.

"A reduction of oxygen to 17-18 per cent of an atmosphere would have no influence on the work done. Mining operations are conducted, railways, etc., are built, and large towns exist at altitudes where the partial pressure of oxygen is much less than this. An increased percentage of carbon dioxide—say up to 1 per cent., will slightly increase the breathing, otherwise it will have no effect. Men in breweries work long shifts in atmospheres of 0·5 to 1 per cent. of CO_2. The whole question of ventilation is one of heat and humidity, so long as poisonous gases (such as CO) are excluded."

"I have animals now, doing well, and putting on weight, living continuously in 2-3 per cent of CO_2 in air which has been breathed by other animals."

A third great authority on respiration, Prof. Benjamin Moore, of Liverpool University, says that a reduction to 17 or 18 per cent. of oxygen will make no difference, and a small amount of CO_2 (about 1 per cent.) certainly is not injurious. He informs the writer that he has had animals in an atmosphere containing 14 per cent. of CO_2 for 48 hours with no ill effects.

In Mr. E. B. Whalley's report* on the ventilation of mines, one place is described where there was a quantity of black-damp given off. It is stated that—

"A light would not burn 1 foot 6 inches from the floor, or in the waste, but the men had no fault to find with the atmosphere, and the fireman told me it was better than usual."

"Three samples of air taken here tested ...	Carbon dioxide. (CO_2)	Oxygen. (O_2)	Nitrogen. (N_2)
	Per cent.	Per cent.	Per cent.
(1) First face on pavement ...	4·56	13·13	82·28
(2) do. at roof	0·69	20·08	79·20
(3) do. at coal-face	1·21	18·97	79·80."

The effect of coal-dust in extending an explosion was noticed over a century ago. The first written record is by John Buddle, who refers to it in his description of the Wallsend explosion, 1803. Faraday and Lyell report on it in 1844 in connexion with the explosion at Haswell.† What is known as the "Coal-dust Controversy" started about 1876, after Prof. W. Galloway read his paper before the Royal Society.‡ That controversy has gone on practically to the present time, being revived in recent years by the explosion at Courrières in 1906, the greatest mining disaster on record, in which over 1,100 lives were lost.

* *Reports of an Enquiry into the Ventilation of Coal-mines and the Methods of Examining for Fire-damp*, by John Cadman, D.Sc., F.G.S., and E. B. Whalley, 1909 [Cd. 4,551], page 68.

† *Copy of the Report of Messrs. Lyell and Faraday to the Secretary of State for the Home Department, on the Subject of the Explosion at the Haswell Collieries in September last* [1844], etc., 1845 [232].

‡ "On the Influence of Coal-dust in Colliery Explosions," by W. Galloway, *Proceedings of the Royal Society of London*, 1876, vol. xxiv., page 239.

Up to 1891 Galloway, Hall, Abel, the Chesterfield and Midland Counties Institution of Engineers, and more especially the Austrian Fire-damp Commission, tried experiments on the large scale—Hall in disused shafts, and the Austrian Commission in a large gallery. The results were roughly as follows:—Galloway, Hall, and Abel could make some coal-dusts ignite with a blown-out shot (or an imitation of one); sometimes they exploded, but sometimes they did not. The final report of the Austrian Commission gives this conclusion among others:—A blown-out shot with coal-dust tamping, or a charge of dynamite lying free, will ignite every kind of coal-dust.

In a former report, this same Commission had classified the various coal-dusts examined into (1) explosive, (2) slightly explosive, (3) inflammable, and (4) safe. One of the dusts described as safe came from Camphausen Colliery, and shortly afterwards an extremely violent explosion occurred there, in the absence of any fire-damp, one of the worst explosions on record, in which 200 lives were lost.

It is interesting to consider some points in the Report of the British Coal-dust Commission, published in 1891 and 1894, as they clearly show the position at that time. The witnesses were about equally divided. One section was certain that some dusts, mixed with air alone, could ignite and explode; the other section was equally certain that coal-dust and air without the addition of fire-damp could not ignite and explode. The latter class were often men who had spent many years in mines, and it must be confessed that they had apparently good grounds for thinking as they did. There are many examples very similar to the following one. A witness, with 57 years' experience, in answer to questions, replied as follows:—

"My experience dates back to 1834, when the mines were much dustier than they are now. The roads were full of dust, and we had many explosions, but they were always in the workings, where it was not so dusty. It was a regular thing to have an explosion, but they were never heavy."

"They were not particular about ventilation in those days. There was not so much air in the pits as we have now. I never knew an explosion take place in dust. I have fired hundreds of shots in dusty places, very dusty places. I have seen many blown-out shots in dusty places, and never the slightest signs of setting the dust on fire." *

* *First Report of the Royal Commission on Explosions from Coal-dust in Mines*, 1891 [C. 6543], vol. i., pages 131 and 134.

This witness concluded by saying: "A lot of people have got coal-dust on the brain."

On the other hand, there were many explosions in positions where gas was impossible, and cases of explosions extending for several miles with very little dust, and certainly no gas. The Altofts explosion, in 1886, is a good clear case of a pure dust explosion, and a very typical one; but the writer does not think it necessary to take up the time of the meeting with a description of this explosion, as the details must be well known to all mining men. The slow ignition, the development of the wave of progressive combustion, and the final wave of extreme violence, approaching a detonation wave, are characteristics of many such explosions on record.

How can these very opposite and apparently contradictory sets of facts be reconciled? There is only one way, and that is by taking into consideration the oxygen contents of the air mixed with the dust.

Two substances take part in a dust explosion—the dust and the oxygen of the air. There has been a great deal written and talked about the dust, but curiously enough the oxygen, which is at least equally important, has been left almost entirely out of the question. It has not been entirely overlooked, but the part which oxygen plays in ordinary combustions has not been appreciated by chemists and others working on dust explosions. They have also assumed that the coal-dust itself acts like a gas such as hydrogen, without any grounds whatever. The following quotation from the Report of the British Coal-dust Committee will show how the experimenters at Altofts looked at the matter. They say: "The impossibility of preventing an explosion taking place by depriving it of the oxygen necessary to propagate combustion is so manifest that it need not be enlarged upon."*

The writer will, however, enlarge upon it for a little while, and thinks that the members will agree that it is by no means so manifest as the authors of the report thought, but, on the contrary, that this is the simplest possible means of preventing explosions.

* *Record of the First Series of the British Coal-dust Experiments conducted by the Committee Appointed by the Mining Association of Great Britain: A Record of the Experiments carried out during 1908 and 1909 at the Altofts Experiments Station*, 1910, page 106.

The writer would like to make a digression here to explain how he came to drift into making coal-dust experiments. Ever since he can remember, it has been his desire to discover a means of preventing coal-mine explosions, and, after every big disaster, he returned to the problem, only to decide over and over again that it was impossible of solution. It was after the Whitehaven disaster that he made a special effort, decided once more that it was an impossibility, but settled down to work on rescue-apparatus. He saw at once that the absurd walking "fitter's shops" called "rescue apparatus" would never be of any use as life-savers, and set out to make one to cost about 30s., and to weigh 14 pounds or so; to be cheap enough to be able to store a good number of them near to or in the workings, and simple enough for any ordinary workman to use without special training. To understand what was required, he procured all the blue books containing the reports of Royal Commissions on explosions in mines, etc., and thoroughly digested them, which was rather a tough task. He soon decided that the reports of the Commissions were not what he wanted, and finally settled on the minutes of evidence of the British Coal-dust Commission published in 1891 and 1894. In studying the evidence of witnesses, it was borne in upon him over and over again that it was always in well-ventilated mines that dust explosions had occurred, and not only that, but, in the best-ventilated parts of such mines, the faces and returns were almost always untouched.

To complete matters, at this time the writer had occasion to study the composition of air, and the conditions under which certain flames went out. He found later that a good deal of this work had already been done by Prof. Clowes many years ago. These three investigations together gave the writer the clue for which he had looked for many years, and he then commenced with coal-dust experiments.

There is an enormous amount of air drawn through the modern mine, and 200,000 cubic feet per minute is quite common. The chief reason for this is to make sure that there are no accumulations of fire-damp, and also, in the case of deep mines, to keep the temperature at a reasonable figure. It is found that, as the air passes through the mine, the oxygen percentage is gradually reduced, and a little carbon dioxide is added. Coal-dust absorbs oxygen, the fresh coal on the tubs

absorbs it too, but the chief factor is that black-damp is constantly given off by the waste in most mines. At the working-face, the fresh coal absorbs oxygen also, and gives off black-damp, so that here the oxygen percentage is always less than in normal air: often it is reduced below 20, sometimes below 19, and occasionally is found as low as 17. Mr. E. B. Whalley reports that the average in mines in Scotland is as follows:—

	Returns.	Working-faces.
Less than 20 per cent. of oxygen	19 out of 52	7 out of 18
More than ½ per cent. of carbon dioxide ...	20 out of 52	7 out of 18

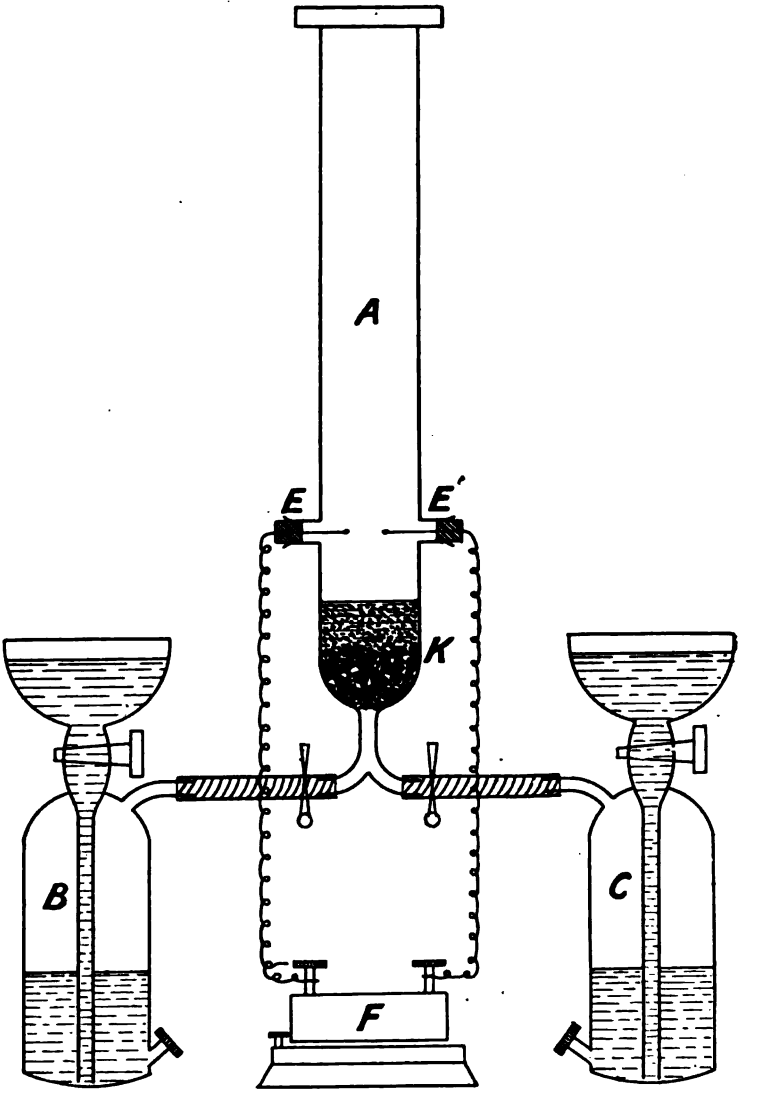
Even when the air in the main returns shows a good percentage of oxygen, it does not follow that the air at the workings is equally high, because near the working-face there is a good deal of leakage from the intakes to the returns—the air becomes short-circuited. Then, of course, the working-faces are the most difficult to ventilate, as they are constantly moving forward.

It occurred to the writer that, as flames of oils and waxes, etc., go out with still so much oxygen present, coal-dust would do so too; and that perhaps this reduction in the oxygen contents of the air at the workings would explain why dust-ignitions never take place there, although these places are often dry and dusty.

To test this idea, the writer fitted up an apparatus similar to the one shown in the figure in the text. This apparatus, for use in testing the degree of inflammability of coal-dusts with air of different oxygen percentages and with small percentages of carbon dioxide, consists of a glass tube A having side tubes E and E', containing corks in which platinum terminals are inserted, leaving a gap of about half an inch. The tube is drawn out at the bottom and provided with a T-piece, one branch of which is connected to a gas-holder B, containing normal air, and the other with a gas-holder C, containing the special air with reduced oxygen contents. A few small pieces of coal or coke are placed in the bottom of the tube A, in order to prevent the tube from becoming clogged at K, and the dust is then placed on top. Several puffs of air from the holder C, containing the special air, are passed through the dust, and a discharge from a powerful coil F is at the same time passed between the terminals E and E' through the mixture of dust and air.

In order to determine the amount of reduction of oxygen and the quantity of carbon dioxide necessary to prevent ignition

of a particular dust, air containing about 18 per cent. of oxygen, 1½ per cent. of carbon dioxide, and 80½ per cent. of nitrogen is



APPARATUS FOR TESTING THE DEGREE OF INFLAMMABILITY OF COAL-DUSTS IN USE IN THE CHEMICAL LABORATORIES AT LIVERPOOL UNIVERSITY.

first tried, so as to make sure that the mixture will not cause an ignition. Some normal air is then let into the same holder and

the new mixture tried, and so on until the air mixed with the dust will just ignite. A sample of it is taken at once, and the carbon dioxide and oxygen are estimated in the usual way.

The gas-holder of normal air is used in order to try the dust from time to time, to show that the spark is strong enough and the dust fine enough and in sufficient quantity.

The writer may here state that the method of ignition does not meet altogether with his approval. The method of ignition, on a laboratory scale, is a very difficult point to settle. It is clearly just as bad to get a source of ignition which is too severe as it is to get the reverse, when one is looking for a method of preventing explosions.

The chief objection to the induction-spark is that it forms ozone, and consumes part of the nitrogen. A continuous-current circuit, broken in the mixture, as used by Prof. W. M. Thornton,* is open to the same objection. The writer hopes to be able to devise a better method of ignition, but the present one is quite good enough for the comparison of different air-mixtures.

The only pure coal-dust with which he has failed to obtain an ignition, when mixed with normal air, is a sample of a South Wales anthracite. It is significant that the experimenters were unable to get an ignition against the current of air with anthracite dust in the Altofts tube. In these experiments, the means of ignition used cannot be described as anything but on the severe side—too much so, in the writer's opinion, to render the results of any practical importance, except in so far as they have achieved the intended object, which was to convince the remaining mine officials not already converted that coal-dust is a very real danger.

Using the apparatus previously referred to, with a coal-dust obtained by grinding coal in a mortar, and employing ordinary air, the writer obtained an ignition every time. He then tried the following mixtures:—

Oxygen. Per cent.		Nitrogen. Per cent.		Result.
16	...	84	...	No ignition.
17	...	83	...	do.
18	...	82	...	do.
18½	...	81½	...	Partial ignition.
19	...	81	...	Just full ignition.

* See "The Ignition of Coal-dust by Single Electric Flashes," by Prof. W. M. Thornton and E. Bowden, *Trans. Inst. M. E.*, 1910, vol. xxxix., page 201.

All the results were obtained under the same conditions. The experiments were, in fact, all carried out and the gases analysed one Saturday afternoon. Since then the writer has tested some dozens of coal-dusts, pure coal-dusts made in the laboratory, dusts from screens, and dusts from various parts of different mines. Some dusts will not ignite with ordinary air, and in the case of those that will, on reducing the oxygen a point is very soon reached at which no ignition takes place. This series of experiments settled the question of the influence of the oxygen percentage.

There still remains to be solved the mystery why the Austrian Commission declared a dust safe which was not; and also the mystery attaching to some of Sir Henry Hall's experiments, which appeared to point to certain dusts being non-explosive, that have since led to most disastrous explosions in the pits.

The writer obtained samples of dusts from the screens, roadways, bars in intake haulage-roads, etc., from a mine working the Barnsley Seam (a seam in which several extensive explosions have occurred). He could not get any of these dusts to ignite in his apparatus, with ordinary air, not even after drying, or after drying and grinding. A piece of the coal from the same seam gave dust which ignited every time. This appeared strange, and especially so in the case of the screen-dust, which appeared to be pure coal-dust. An analysis of the dusts gave the probable explanation:—

		Per cent.
Ash in screen-dust		10·4
,, dust from intake haulage-road	(1)	33·9
,, ,, ,, ,, ...	(2)	19·5
,, dust from coal, made in laboratory		1·3

It is interesting to note that, although the screen-dust would not ignite with ordinary air, it did with air in which the oxygen was increased from 21 to 23 per cent.

The writer next took a quantity of the same screen-dust, and made an air-separation by blowing air through it, and settled the fine dust. This fine dust was tested in the apparatus with ordinary air, and it ignited.

One has now the explanation of the behaviour of dusts such as those declared to be safe by the Austrian Commission, which were not safe, and those that Sir Henry Hall's experiments

appeared to indicate as safe, which were not safe either. They were not pure coal-dusts, but dusts taken from the mine, and in the experiments were mixed with pure air, while in the mine they were mixed, not with pure air, but with air containing a considerable amount of dust (dust which, it has just been shown, is more inflammable than that settled out). Only it is probable, in fact certain, that this dust is still more inflammable than the writer's experiments indicate, because the screen-dust, when he got it, was already bereft of the still more inflammable dust removed by the air-current in the mine and at the screens.

The writer's apparatus will show, in a few minutes, which dusts in a mine are very dangerous, and which are not, but it will not show that a mine is safe, unless the mine-air itself is used. The experiments must therefore be carried out near the colliery, and that would necessarily be a somewhat tedious process. The fact is mentioned, lest some managers should test their dust-samples with pure air, and be lulled into a state of false security by the results obtained.

The writer has no doubt in his own mind, for instance, that the intake haulage-ways of the mines working the Barnsley Seam contain an explosive mixture of dust and air, and that a train of runaway tubs and a broken lamp together are all that is required to give an explosion in these pits. The velocity of the air-current is so great that every section would be traversed by the explosion, right up to the working-faces, and then, if there was any gas, through them and the returns as well. It must always be borne in mind that it is the dust in the air which is the important factor (aided by the other dust) in an explosion. The pure dust from the Barnsley Seam coals ignited with ordinary air every time, and it was found that the oxygen had to be reduced to 18¾ per cent. to just prevent ignitions, or, when using a very powerful flaming spark, to 17½ per cent.

The writer found that carbon dioxide has a marked influence on the ignitions, and that a mixture of 19¼ per cent. of oxygen, 80 per cent. of nitrogen, and ¾ per cent. of carbon dioxide acts much in the same way as one containing 17½ per cent. of oxygen and 82½ per cent. of nitrogen.

The action of various atmospheres on the ignition of some few examples of coal-dusts, and coal-mine dusts, will be seen from the data supplied in Table II.:—

TABLE II.—SHOWING THE DEGREE OF IGNITION OF DIFFERENT COAL-DUSTS WITH VARIOUS ATMOSPHERES.

Dusts.	Percentage of Ash.	Normal Air.	Air: 19·3 per cent. of Oxygen and 0·65 per cent. of Carbon Dioxide.	Air: 19·2 per cent. of Oxygen and 0·9 per cent. of Carbon Dioxide.	Air: 18·0 per cent. of Oxygen and 1·5 per cent. of Carbon Dioxide.
Barnsley Seam—					
Pure coal-dust—(1*)	1·3	Full.	Just full.	Partial.	—
do. do. (2*)	—	do.	do.	do.	—
do. do. (3*)	—	do.	do.	do.	—
Screen-dust	10·4	None.	—	—	—
Dust from timber in haulage-ways—(*a*)	19·5	do.	—	—	—
do. do. (*b*)	33·0	do.	—	—	—
Lancashire Coal ...					
Arley Coal*	—	Full.	Full.	Full.	None.
Three-Quarters Coal*	—	do.	do.	Nearly full.	do.
Plodder Mine* ...	—	do.	Just full.	Partial.	do.
Yard Coal*	—	do.	do.	do.	do.
Arley Mine dusts (*a*)	7·7	None.	None.	—	—
do. do. (*b*)	17·1	do.	do.	—	—
do. do. (*c*)	25·9	do.	do.	—	—
Three-Quarters Mine dusts ... (*a*)	50·0	Full.	do.	—	—
do. do. (*b*)	36·0	None.	do.	—	—
do. do. (*c*)	37·0	Partial.	do.	—	—
do. do. (*d*)	33·4	do.	do.	—	—
Plodder Mine dusts (*a*)	14·8	Full.	do.	—	—
do. do. (*b*)	22·5	do.	do.	—	—
Yard Mine ... (*a*)	23·1	do.	do.	—	—
do. (*b*)	24·5	do.	do.	—	—
Wigan—					
Arley Mine dusts (*a*)	—	do.	do.	—	—
do. do. (*b*)	—	do.	do.	—	—
Blackburn—					
Mountain Mine Coal*	—	Full.	do.	—	—
Mine-dust	11	None.	—	—	—
Screen-dust	—	do.	—	—	—
South Wales—					
Ferndale Coal* ...	—	None.	—	—	—
Mine-dust	—	do.	—	—	—

* These dusts were made in the laboratory from samples of fresh coal.

There are many phases in a great coal-dust explosion with the two extremes, namely, the ignition and the detonating explosion (or something approaching a detonation), and there is evidence that an explosion in a mine can wax and wane. For the ignition there must be a large excess of coal-dust, much more than can be burnt to carbon dioxide and water; the ignition is

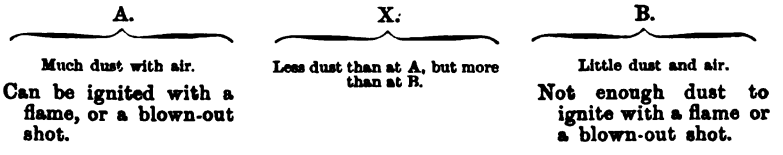
therefore not violent, because from this excess of dust a large quantity of carbon monoxide is formed, and the reaction ($2C + O_2 = 2CO$) does not give off a great amount of heat.

The quiet slow combustion does give off some heat, however; it gradually gets up speed to a certain point, and the wave of progressive combustion may overtake the wave of compression, which moves in front, throwing up the dust in excess. Now, when this wave of progressive combustion overtakes the other, there is a different state of things. The dust is no longer in excess, but it may be in about the right proportion to burn to carbon dioxide and water, in which case a violent explosion occurs; and, if the air in the rest of the mine is mixed with sufficient fine coal-dust (and very little is required), favourable conditions for a violent explosion exist, and the explosion races through the dust and air at about 50 miles per minute.

Almost without exception coal-dust explosions are confined to the intake ways that are dusty, and seldom if ever traverse the workings or return airways, many of which are also dusty. A stretch of damp road, 100 yards long or so, will stop an ignition, probably because there is not sufficient dust in the air to propagate it; also a stretch of stone-dusted road less than 100 feet or so will stop it, provided such dust is fine and pure. Such explosions have all occurred in well-ventilated mines, and in the best-ventilated parts of such mines. One never reads of a big dust explosion in a badly-ventilated mine. The explosion always takes place against the current of air; sometimes it goes in the other direction as well, but seldom reaches the working-faces; generally, this branch is an ignition which fails to develop explosive violence.

Obstacles in the path of the ignition invariably increase the speed and violence. The explosive violence is developed sooner with obstacles present. This is because such obstacles retard and reflect the wave of compression, which allows the combustion wave to overtake it sooner. It will be gathered from this view that the conditions for an ignition, and for a violent explosion of dust, are quite different. For an ignition an excess of dust is required, but for a violent explosion about the right amount of dust for complete combustion. A violent explosion will not traverse an excess of dust, but will be slowed up to the ignition pace; and, on the contrary, a mixture of dust and air

at B, with so little dust that it cannot be ignited with a flame, will propagate an explosion started at A if the explosive violence has developed sufficiently by the time it reaches X.


A.
X.
B.
Much dust with air.
Can be ignited with a flame, or a blown-out shot.
Less dust than at A, but more than at B.
Little dust and air.
Not enough dust to ignite with a flame or a blown-out shot.

One phenomenon always noticed after a big dust explosion is that coked dust is found plastered on the sides and top timbers and on the floor of the ways. Curiously the coked dust is found plastered on the timbers on the side opposite to the one facing the origin (except near the origin, when it may be found on either or both sides) of the explosion. The explanation of this first case is that when the violent explosion passed, there was no coked dust to be plastered; the clouds of dust are whirled into the air behind the explosion wave, and then they are burnt to carbon monoxide and coked dust, which is plastered on the timbers by the return wave, due to the contraction of the cooling gases, or by a return wave similar to that often observed in gas explosions.

There are 50 million shots fired every year in the mines of this country, and most of them are fired at the working-faces. It is true that a good many workings are damp, but there are many that are dry and dusty, especially in deep mines, which are hot, and yet ignitions of dust are unknown there. The writer would again call the attention of the members to what the witness previously quoted said in his evidence—hundreds of shots in very dusty places, many blown-out shots, no tendency for the dust to fire, and not much ventilation. The oxygen percentage could not have been much if at all below 19, or their candles and lamps would not have burnt properly. This evidence is only a sample, and the writer could give numerous other similar extracts. There appeared in the *Coal Age* of February 3rd, 1912, an article by Mr. John Verner, of Charlton, Iowa, U.S.A., on "The Causes of Iowa Mine Explosions." These mines are dry, but non-gaseous; they are subject to explosions when just developed, but are immune when further extended. Mr. Verner describes several cases of explosions in new mines, and as the mines became more extended, the same furnace was used for the ventilation and the current of air was slower. At one mine (No. 4), in

Lucas County, there were three explosions in one year, but the danger was recognized, and the shots were fired when only the shot-firers were in the pit, and they were killed. No change was made in the system of working, and no further explosions took place during the following 6 years, at the end of which time the mine was exhausted. The dust increased as the mine extended, and there was no perceptible decrease in the number of blown-out shots. Of the three explosions mentioned, two were caused by blown-out shots improperly prepared and overcharged, and one by shots which had done their work fairly well and were not overcharged.

If the experiments described by the writer be considered in conjunction with all the evidence of what has taken place in actual mine explosions, of which two samples have been given, any reasonable person must admit as a fact that not only will an atmosphere with a slightly smaller oxygen percentage than the normal prevent a coal-dust ignition, but that an explosion of coal-dust mixed with air with a slight deficiency of oxygen cannot be propagated.

The very rarity of coal-dust explosions points to the fact that normal air with its 20·9 per cent. of oxygen is near the border of the lower oxygen limit for ignitions of even pure coal-dusts (in fact, it is below for some South Wales anthracite coal which the writer has tested), and that a very slight reduction—say to 20 or 19½ per cent. of oxygen, with ½ per cent. of carbon dioxide present, will be sufficient to make the intake ways of a mine as safe as the working-faces are now in mines where the ventilation is not excessive.

Large dust explosions unaided by gas are a modern production, and may be said to date from and be caused by the Coal Mines Regulation Act of 1872, and the subsequent laws passed during the last 40 years. These Acts, and the presence of the mine inspectors, have increased the speed of the ventilating current more and more, thus removing the many small fire-damp explosions with the right hand, and giving the few big dust explosions with the left.

The Mines Act of 1911, which comes into force in a few months, will again increase the velocity of the air. When the provisions of the Act are carried out, the danger zone will be carried farther in—perhaps to the very working-faces (as indeed it

is now with many excessively ventilated mines); then in every dry mine a chance ignition of gas or dust in any part may mean a tremendous dust explosion through the intakes, faces, and returns. At present Providence—not good management—has arranged that the air at the working-faces should contain less oxygen than the normal, by about 1 per cent. in many mines, and also that there is ½ per cent. of carbon dioxide, which makes them safe. In actual practice, a dust ignition cannot originate there, or a dust explosion be propagated through such workings.

In discussing the prevention of explosions, it is as well to decide at once that it is impossible, at a reasonable cost, to keep the air of a dry mine free from that small quantity of dust which is all that is required for the propagation of an explosion. The dust is there floating in the air, practically as soon as it has passed the intake shaft; and when it is remembered that the roads of even a small mine are from 10 to 15 miles long, the possibility of keeping them free from dust may be dismissed.

The only way to prevent absolutely coal-dust explosions is to leave nothing to chance. At the present time, the dry mines in this country are more dangerous than they were several years ago, and, if the Government has its way, are likely to become more so in the future; yet the remedy is very simple. A reduction of 1 per cent. in the oxygen content, and the addition of ½ per cent. of carbon dioxide in the ventilating current, is all that is required for most mines; and for the more dangerous mines—those with very inflammable dusts—a reduction of 2 per cent. in the oxygen content, and the addition of about ¾ to 1 per cent. of carbon dioxide, would make the intake ways absolutely safe. The practice of having doors between the intakes and returns should be avoided as much as possible; only absolutely essential ones should be left, and these made very small and very strong. Coal-mines could be made absolutely safe from explosions of dust and fire-damp, and fires, by reducing the amount of oxygen in the air to 17½ per cent.

Marsh-gas is very sensitive to a reduction of oxygen, the limits with ordinary moist air being about 6 to 13 per cent. of marsh-gas; the lower limit is a very doubtful number, much work has been done on it, and only recently a very fine scientific research has been published by Messrs. Wheeler and Burgess.*

* *Journal of the Chemical Society, Transactions*, 1911, vol. xcix., page 2,013.

Unfortunately, the figures which they obtain are useless for practical mine purposes, as the method of ignition employed—a spark from an induction-coil—puts it quite out of court in the writer's opinion.

The writer made an experiment some time ago with impure marsh-gas—a mixture of 15 volumes of oxygen, 85 volumes of nitrogen, and 7½ volumes of impure marsh-gas. The mixture would not light with an ordinary match or gas-flame, and the writer thought that he would like to ascertain the cap that it gave with an induction-spark, so he filled a glass bulb in which were fitted platinum terminals, switched off all the lights so as to see the cap, and sparked it. Nothing was seen, but a good deal was heard, and it took a considerable time to find the platinum terminals.

Some later experiments, using marsh-gas freed from hydrogen, but probably not pure from other hydrocarbons, gave the following results:—

	(1) Volumes.	(2) Volumes.	(3) Volumes.
Oxygen ...	16	17	17½
Nitrogen ...	84 / 100	83 / 100	82½ / 100
Marsh-gas ...	8	8½	8⅜
Results—	No ignition with small gas-flame.	No ignition with small gas-flame.	(1) Tube mouth upwards: no ignition; (2) tube horizontal: no ignition; (3) tube mouth downwards: ignition.

A jet of marsh-gas (containing other hydrocarbons) and 3 per cent. of hydrogen, when burnt in a closed space, went out when the air contained 1·3 per cent. of carbon dioxide and 18·4 per cent. of oxygen. Using the same gas in a bigger vessel, and circulating the air, the jet went out on the air sample containing 1·7 per cent. of carbon dioxide and 17·3 per cent. of oxygen.

The writer finds that with tests done in a closed space, and without circulation, the test of the air is always higher in oxygen than when circulation is carried on. The old figure given for a candle, namely, 17½ per cent., has probably been arrived at without circulating the air. The writer finds that 16·9 to 17 per cent. is nearer the mark when the air is circulated.

An atmosphere containing 17½ per cent. of oxygen is ideal for a mine, if it were not too expensive to make and maintain. The advantages of such an atmosphere in a mine are as follows:—

(1) Coal-dust ignitions would be rendered impossible, and explosions of any kind quite out of the question.

(2) The chances are enormously against even an ignition of fire-damp, however much or little may be present.

(3) A fire of timber or coal starting in the roads would be impossible. It is moreover almost certain that a gob-fire could not originate; but, granted that it might, it would be impossible for the fire to spread or to become a source of real danger.

For respiration, 17½ per cent. of oxygen is as good as 21 per cent. One may go further and say that for a mine it is better, provided not more than about 1 per cent. of carbon dioxide be present. It has been shown by many observers investigating this matter, that a reduction in oxygen tension is a cure and a preventive for consumption.

The problem of lighting a mine with this 17½ per cent. of oxygen atmosphere is solved by the use of electric lamps, or, what is better, by acetylene lamps. Acetylene continues to give a fair light with 12 per cent. of oxygen, and it does not go out until 9½ per cent. is reached. These lamps would be quite as cheap in first-cost, and to maintain (if there was the demand for them), as ordinary lamps. A great advantage is that an acetylene flame requires for combustion about the same percentage of oxygen as a man does for respiration, at normal pressure: so that while his acetylene lamp burns, and gives any light, he can breathe with safety, provided, of course, there is no carbon monoxide present; and, instead of being in doubt about the air, he can tell with a little practice roughly the percentage of oxygen present. Such a lamp is, therefore, in some ways better than an electric lamp.

It is also possible to ascertain the oxygen percentage in air by taking advantage of the fact that different combustibles go out at different oxygen percentages. Probably the best way, when the oxygen is above 17½ per cent., is to use a candle-flame, as by the light or the length of the flame it is possible to determine the percentage of oxygen to about ½ or less.

An atmosphere containing 17½ per cent. of oxygen is not necessary to prevent dust explosions, and, in addition to this,

the new Mines Act of 1911 fixes the minimum of oxygen at 19, and the maximum of carbon dioxide at 1¼ per cent. The writer thinks it must be agreed that, where oil-lamps and candles are used, this is a reasonable standard; but, if the composition of the air had been left without restriction, and the wretched glimmer of light which is tolerated now had been abolished, the new Mines Act would have done much more good, as many of the fatal accidents in mines are indirectly due to the miserable lights with which the miners work. The practical proposition is, therefore, to use an atmosphere containing 19 to 19¼ per cent. of oxygen, with some carbon dioxide (¾ to 1 per cent.), for the dangerous mines; and 20 per cent. of oxygen, with ½ per cent. of carbon dioxide, for the majority of mines. This may be obtained in any well-known way; but, taking into consideration the enormous volume of air pumped through a modern mine, probably the only feasible method is to use flue-gas, taking special precautions against the formation of carbon monoxide, then to remove the dust, smoke, sulphur dioxide, and finally to make sure of the complete absence of carbon monoxide. One part to 30 of fresh air, or 1 part to 15 in the case of dangerous mines, should be put into the air entering the mine.

For purifying the flue-gas, some simple plant would be necessary, but the capital outlay would be small, and the working-cost very little if anything extra. The same plant would be of enormous value in case of a fire breaking out in the pit; the oxygen contents could be quickly reduced to retard it, and, when the men were out, further reduced to any desired extent. The percentage of oxygen could then be increased to 14 or 15 per cent., and men sent in to examine the workings. A man can breathe this mixture quite safely, even with the carbon dioxide in it; and, with a simple pocket carbon-dioxide absorber, such as a Towers respirator, he can do so in comfort.

The PRESIDENT (Mr. George B. Harrison) said that whether they agreed with the views propounded by Dr. Harger or not, they were greatly obliged to him for his paper. Although the views set forth by the writer ran counter to those which they had held for a lifetime, from the chemical point of view Dr. Harger knew his facts. Whether when those facts came to be considered

from the mining point of view, and were put into practice, he would be quite as certain of them as he was now, the future would show. But they as mining men were pleased that there were eminent scientific men like Dr. Harger, able and willing to give time and thought to the consideration of mining problems, and anxious to do something towards the prevention of disastrous explosions.

Mr. Alfred J. Tonge (Hulton Collieries) had great pleasure in moving that the hearty thanks of the meeting be accorded to Dr. Harger for his paper. Dr. Harger had explained the effect of the varying percentages of oxygen, and had given excellent authorities for his views, and if his conclusions were sound, it meant that speeding up the air was not flying from danger, but in the face of it. The matter could not, therefore, be left there. He had met two or three men who had said that Nature or Providence had arranged that human beings should breathe air containing 21 per cent. of oxygen and 79 per cent. of nitrogen; but he did not think that they need invoke the aid of Providence in such a matter. If they did, they would have to begin, he thought, at an earlier stage than that. To follow such an argument to its logical conclusion, they might assume, for instance, that if it had been intended that they should burrow underground for coal, they would have been provided with a different eye—one probably more like that of the fishes of the deep sea, capable of seeing in comparative darkness, and not one subject to miners' nystagmus. When they commenced to burrow underground, they were entering into what might be called "artificial" conditions, and had therefore to resort to artificial means to assist them.

With regard to the question of increased ventilation, it seemed to him that the exponents of the speeding-up of ventilation had some awkward questions with which to deal. There were a number of difficulties in the way when they speeded up their air, especially in regard to the corners which it was said must be ventilated. Again, there were many mining engineers who were now relying more or less on stone-dust distribution. It was possible that such a remedy as stone-dust was not so efficacious as they were inclined to belive. As the air-current was increased, more coal-dust was brought out of the corners, more stone-

dust would be put into the air, and some of this stone-dust might be bad for respiration. It was quite true that British mining life was considered at present good for persons troubled with lung disease. Would it, however, continue to be quite so good when the air was speeded up so much and mixed with a quantity of stone-dust, or if watering was introduced still more abundantly?

He considered that Dr. Harger ought to be encouraged in every possible way to continue his experiments. Probably, some of the members, if they spoke candidly, would ask Dr. Harger to make sure that he had not had a few, so to speak, coincidences in his experiments. Had he collected sufficient data to make certain that he had reached a final conclusion? Had he had sufficient experience as to the effect of density, and of drying the air and dust? As to the question of mixing the air with flue-gas, he thought that it would be quite possible—indeed, comparatively easy—to get the mixture required.

Mr. Robert Winstanley (Manchester), in seconding the motion, said that the mining men of this country were to be congratulated on having men of distinction and scientific attainments, such as the lecturer, intent on helping them to solve the problems with which they were constantly confronted. Certainly, after listening to Dr. Harger, he had begun to wonder what they had been doing all these years, and whether they would not have to go back and forget a good deal that they had learnt. Clause 29 of the new Mines Act provided that the ventilation of any mine should not be considered perfect unless there were 19 per cent. of oxygen present in the atmosphere. What, then, were colliery managers to do? He suggested that, instead of indulging in carping criticism on the theories of Dr. Harger, they should encourage him in every way. Some of his statements made one feel almost uncanny when they remembered what they had been doing and learning from experience in past years. He would ask them to weigh carefully what Dr. Harger had said, and if they were satisfied that there was any foundation of truth in his theory, then to devise means to obtain the proper mixture of oxygen and carbon dioxide. What would be the effect of such an atmosphere several hundreds of yards from the shaft-bottom, or, say, 2 miles away, with the varying conditions and changes of the air-current? In one

colliery with which he was connected a return-air analysis was made about once a week, and in the same return air, at different points, different results were obtained. That being so, what effect would Dr. Harger's method have on the general ventilation? He thought, therefore, that they ought not simply to listen to and then put aside these questions, but ask Dr. Harger to continue his experiments and let them know the result of his further investigations.

The vote of thanks was passed with acclamation.

The PRESIDENT said that if the oxygen percentage in a mine were reduced to the limit beyond which an ordinary light would not burn, how were they to know, if working, say, with an electric lamp, the exact condition of the atmosphere and whether there was still a margin of safety? What guarantee was there that they would be warned in time of any change in the atmosphere? They had had, he thought, in the Lancashire district, since he came to it, more outbursts of gas of one kind or another, mainly of fire-damp, than explosions. They had had some serious outbursts of gas brought about in a very short time, and the air had suddenly become fouled with fire-damp. He knew of instances where men whose lights were put out at the working-face were able to come out in the dark on roadways fouled for long distances, and were saved. The colliery manager had to consider whether, if they reduced the oxygen to the low percentage now suggested, those men would have had sufficient margin to enable them to get to their destination in safety. The men had travelled on sleds, or trams, so that once on them, although without lights, they were conveyed speedily along the roadway. If they had been travelling without a light in the ordinary way, they would have been compelled to grope along, which would have taken a long time, and they were in a foul atmosphere. In his younger days they had experienced more trouble where he was employed with outbursts of black-damp than with explosions, and in those days he had an idea that sometimes they got very near the limit of exhaustion owing to the fouling of the air. If, however, they could secure the great boon of immunity from explosions at the risk of the loss of one or two lives, it was a matter worthy of consideration. As a considerable time must necessarily elapse before the changes suggested could be brought about, there was ample

opportunity for this question to be threshed out. Let the matter be thoroughly discussed, and if the proposal were deemed feasible, the mine-owners would no doubt try to adopt it. It must be remembered that Dr. Harger knew his facts from a chemical point of view, and doubtless from what he had said persons could live in an atmosphere containing less than 21 per cent. of oxygen. Whether this amount would be considered sufficient if a man were working in the mine continuously, he did not know. In his youth old miners used to attribute their bronchitis or asthma to their working in the pit, and set down their illness to the bad state of the mines. It might have been imagination only on their part, as with others who thought that their lives were endangered because their lights would not burn.

Mr. GEORGE H. WINSTANLEY (Sheffield) wrote that, assuming for the moment that the almost insuperable difficulties of putting Dr. Harger's proposals into operation had been overcome, and that it was possible to maintain, in all parts of the mine, a constantly artificial atmosphere, there still remained the fact that the proposal was based upon an entirely fallacious assumption that the excess of oxygen which the normal atmosphere of a mine provided could be dispensed with. The fact that places like St. Moritz and Davos, with their cold dry atmosphere, situated at altitudes which gave a partial pressure of oxygen something like that proposed by Dr. Harger, were health-resorts adapted for the requirements of consumptives did not constitute evidence that a similar permanent reduction in the proportion of oxygen would enable miners to carry on their laborious work in temperatures of 80°, 90°, or even 100° Fahr. From the coal-face to the delights of these Swiss health-resorts was a far cry, and conditions were met with in coal-mines which were unknown at Davos.

In approaching the general question of explosions in mines, the sense of proportion must not be lost sight of. The effects of such explosions were terrible enough, it was true; but, as the President had recently demonstrated in his Address, colliery explosions were by no means the most serious dangers met with in mines. The question, therefore, whether it was wise to introduce a new and most serious element of danger, in order to mitigate one which, although terrible, was not so serious in magnitude as the non-mining public possibly imagined, was one that required most serious consideration. Most of those who were colliery

managers could give evidence, from their own personal experience, of occasions—by no means rare—when even with a normal atmosphere a sudden outburst of gas had put out all the lights, and perhaps reversed the ventilating current. In such cases one was thankful that the atmosphere contained such a liberal amount of oxygen that these outbursts still left the air sometimes—although not always—in a respirable condition. What then would be the effect in a mine where the oxygen percentage had already been deliberately reduced—where the "margin of safety" had been impaired and encroached upon?

What did colliery managers do with their winding-ropes when the margin of safety became impaired, although the ultimate tensile strength was still greatly in excess of the load? Dr. Harger invited those in charge of coal-mines to sacrifice, or at least to impair, the margin of safety. The long record of fatalities in the past and mining experience forbade one to do any such thing, and if Dr. Harger had gone through the experiences underground which many of them had sustained, he, too, would hesitate to tamper with a wise provision of Nature.

Taking the case of a working district in a deep mine far removed from the shaft, and assuming that the ventilating current had been intentionally robbed of oxygen to the extent proposed, and that a sudden outburst of gas occurred, what would become of the workmen? Since safety-lamps, in an atmosphere which would not support combustion were obviously useless, how would it be possible for the workmen to keep themselves informed as to the state of the atmosphere? How would they know when it was becoming unfit for human respiration? Had Dr. Harger ever had the experience, which most mining people had, of finding himself in an atmosphere which—although it did not actually extinguish the lamp—nevertheless occasioned serious discomfort? If so, were his sensations such that he would have been content, not merely to remain in such a place for a time, but to engage in continuous laborious work day after day?

Finally, could Dr. Harger, or any other authority, positively prove that the health of the miner, working under conditions ordinarily met with in mines, plus the circumstances he proposed to establish, would not suffer, or that his vitality would not be impaired, always remembering that the most strenuous part of the men's lives would be spent under such conditions.

Until these points were definitely cleared up, and positive assurance given thereon, discussion on the merits of Dr. Harger's proposals was not reasonably possible or profitable; but he (Mr. Winstanley) would remind the author that in what he now proposed he practically asked them all to revert to the condition of things which prevailed in mines more than a century ago, for his idea was by no means new; it was—unintentionally, no doubt—practised a century ago; and the records of mining disasters were not so bright as to make one desire to re-establish those former conditions.

He would refer Dr. Harger to a living authority who could tell the members of his own experiences under such conditions; indeed, those experiences were recorded in the *Transactions* of the Society by an Inspector of Mines, Mr. Joseph Dickinson, whose practical knowledge of mining extended over three-quarters of a century.

Mr. Leonard Fletcher (Atherton) said that he would like Dr. Harger to make it clear to the members that men could work in an atmosphere, containing only 17½ per cent. of oxygen, continuously as a miner had to do, for 7 or 8 hours, for it seemed to him that men who worked in a rarefied atmosphere at the heights mentioned by the lecturer lived at those heights and were accustomed to those conditions. They became acclimatized, but a collier would have one kind of air to breathe in the pit and another when he was above ground; he would get 17½ per cent. of oxygen in the mine, and on leaving it he would breathe an atmosphere containing an additional 3½ per cent. Dr. Harger had also referred to the coal-dust at the coal-face as being in much greater quantities than on the roads. This was contrary to one's experience, and he would like to have the first point made clear.

Mr. Sydney A. Smith (Manchester) said that, in his opinion, there were two or three great questions brought forward for them to consider as mining men. They had learnt a great deal from what Dr. Harger had told them that evening; for example, that coal-dust would not fire when the quantity of oxygen in the air was reduced to about 17½ per cent. But assuming for a moment that all that Dr. Harger had said was correct, that it was possible to carry out his proposal exactly as he had suggested,

and that the mechanical arrangements for supplying this flue-gas were properly controlled, would it be an advantage to the miner? He thought that most mining men who considered this subject would want to be satisfied that it was going to do some real good. There was first of all the danger of putting flue-gas into the mine. He supposed that it would require some nicely-regulated machinery in order to maintain the exact proportion of flue-gas for mixture with the air going into the mine. If the amount of oxygen were reduced to 17½ per cent. when such quantities of air as 500,000 cubic feet per minute were going into the mine, and a large quantity of flue-gas, say 16,000 cubic feet per minute, was necessary, and an accident happened to the machinery, or a fall occurred in the roadway, and the air-current was suddenly reduced to, say, 300,000 or 250,000 cubic feet per minute, and the machinery continued to send in the same amount of flue-gas, what would be the effect? The amount of oxygen would be reduced to very much less than 17½ per cent., and the amount of carbon dioxide and carbon monoxide increased to possibly poisonous proportions.

There was another point: statistics showed that for the last 18 years the average number of deaths of miners by accidents from all causes underground was about 1·5 per thousand per annum. Of these total deaths about 12 per cent. were due to explosions and the rest to falls of earth and various other accidents. Therefore, the risk from explosions to persons employed underground was comparatively small, even taking into consideration the terrible explosions which had occurred where there had been heavy loss of life. It was generally known that the miners' work was considered one of the healthiest occupations, and it had been stated that there were fewer cases of consumption among miners than in any other calling. Would it be wise, therefore, to turn these deleterious gases into the air going into the mines, in order to reduce the amount of oxygen from 21 to 17½ per cent.? A miner knew now what risk he ran from explosions. It was small, but he (the speaker) thought that to take a percentage of the oxygen out of the atmosphere, as suggested, would tend to lower the vitality of the miner (if he were constantly working in it), and would most likely make him more subject to disease, thus causing a higher death-rate among such workmen. With regard to risks

of accident, they were inevitable in all occupations, and even in sport or when travelling. Personally, he (the speaker) would prefer to go down a mine and run the small risk due to explosion, than work day after day in an atmosphere in which the oxygen had been reduced to 17½ per cent. Then apart from carbon dioxide there was the carbon monoxide—a varying quantity in flue-gas. It was a most poisonous gas, and one that should not be played with. Assuming that Dr. Harger's proposal was workable and that it reduced the risk of explosions, would not the cure be worse than the disease? The dangers inseparable from mining were quite bad enough at present; would they not be made worse if the air were vitiated with flue-gas with all the risks attending its use? He thought that the miner would prefer to have the mine ventilated with fresh air, containing 21 per cent. of oxygen, and to run the risk of explosion, rather than to adopt Dr. Harger's suggestions.

Mr. JOHN GERRARD (H.M. Inspector of Mines, Worsley) said that there could not be the slightest shadow of a doubt that mining men welcomed with open arms all men of science who came forward to help them, to enlighten them, and to make mining safer, which was, indeed, what they as mining men were continually striving for. Dr. Harger had given a shock to him, and he imagined to many others who considered themselves as practical mining men. He (Mr. Gerrard) had only one or two ideas to put forward. He took it that the normal percentage of oxygen in the air was 21, and Dr. Harger advocated reducing it to 17½, which was a reduction of 3½ per cent. What was the margin? By how much more could the percentage be reduced without operating prejudicially upon the miner? They had prided themselves upon the healthiness of the occupation of those engaged in mining, and had over and over again put forward their views that the health of the miner was almost equal to that of the agricultural labourer. They did know that all mines were not alike, and if outsiders would recognize that a little more readily, it would be better. Take the Dow Mine. Those who had to do with that mine knew the avidity of that seam for oxygen, with the consequent result—frequent gob-fires. Now, if the percentage of oxygen was reduced below 17½, which would be the starting point in the case of the Dow Mine, it might be prejudicial to the worker. Must they

accept Dr. Harger's statement, that if they had only 17½ per cent. of oxygen in the air they would have no more coal-dust explosions, no more fire-damp ignitions, and no more gob-fires? The prospect was very attractive, he must confess; and the more one looked at it, the more one liked it. They wanted to be assured, however, that this freedom from those three terrible dangers would not injure the healthiness of the miners' occupation. He had been anxious to know whether Prof. H. B. Dixon was present, and he was very glad to see him there. They looked upon him as the greatest authority, in Manchester, on the chemistry of mining, and he was sure that they would all be grateful if Prof. Dixon would favour them with a few observations on the subject of Dr. Harger's paper.

Prof. Harold B. Dixon (Manchester University) said that as he had been called upon in this way, he could hardly refuse to say something on the subject before the meeting. At the same time, he must remind them that he was engaged as one of the judges, so to speak, in trying different methods for arresting explosions. In these circumstances, he did not propose to give an opinion on the merits of Dr. Harger's proposal, but he would like to say how very glad he was to find a man like Dr. Harger working at the subject month after month and giving them the benefit of his experiments and experience. They must, of course, remember that safety in the mine was not to be won all of a sudden by one discovery. It would be a long and tedious process. But every little helped, and he welcomed many of the things that Dr. Harger had brought before the Society. He believed it to be true that some reduction of oxygen might be made in the air without anyone seriously feeling it. Certainly, they might ascend 3,000 or 4,000 feet above sea-level and work tolerably well. He was not sure whether they were all equally immune from the effects of carbon dioxide in the air. He believed it to be the fact that if about 1 per cent. of carbon dioxide were present in the mine air, some of them did feel it quite markedly; and beyond 1 per cent. he thought that there was no doubt about it. Dr. Haldane said that anything up to 1 per cent. might be innocuous, but anything beyond that amount might be seriously felt. He was glad to have heard that practical mining men would be willing to try Dr. Harger's pro-

posal; but, then, if they were ready to do so, he felt that great precautions should be taken, if flue-gases were actually used, to prevent any carbon monoxide from going down the mine. In any case, they would have to adjust very carefully the amount of such flue-gas to the total intake of air.

He understood Dr. Harger to say that gob-fires would exist no longer, and that there would be no danger from coal being burnt, if the supply of oxygen were cut down to between 17 and 18 per cent. He was not sure on what experiments Dr. Harger had founded that statement. Dr. Haldane had some years previously published a paper in which he showed that coal would burn slowly with a very small percentage of oxygen in the air, and that there was no definite point at which it might be said that the coal would go out. It was quite a different matter from a flame becoming extinct. No doubt some flames were very sensitive to the percentage of oxygen and the amount of carbon dioxide in the air; but he would like to ask Dr. Harger these two questions:—Supposing that it were to happen that the flame of a lamp, for instance, would go out when the oxygen was reduced to 17 per cent. at the ordinary pressure. Now it often happened that one had a blown-out shot where a large flame and considerable pressure were produced, and that, it occurred to him, might cause the ignition of a mixture of fire-damp, even when the percentage of oxygen was below 17. Had Dr. Harger tried that experiment? If not, surely it should be tried. Again, Dr. Haldane had found that gas from a goaf might be extinctive to flame when largely diluted with air, and yet become explosive when less diluted. He had fired mixtures of black-damp, fire-damp, and air when the percentage of oxygen was as low as 13 or 14. So even if the lamp-flame went out, it seemed that they wanted a proof that an explosion was still impossible. And then there was the pretty experiment of the dust being fired by a spark in ordinary air, but not with 17 per cent. of oxygen. In that room there was the usual atmospheric pressure, but there were occasions when there was a sudden pressure-wave. Supposing that there were such a pressure-wave, and one had a mixture of fine coal-dust and air: what would be the result of the flame of a blown-out shot? He thought that they wanted evidence that if the pressure were increased, and the oxygen percentage lowered to the point suggested, there

would be no danger in the mine. It would not be difficult to test these points experimentally; perhaps Dr. Harger had done so. Until these questions were answered, it could not be said that Dr. Harger's proposal would ensure safety from explosions in mines.

Mr. VINCENT BRAMALL (Pendlebury) said that Mr. Gerrard had referred to the Dow Mine. The fact was that work in that mine was more exhausting to the men than it was at the same temperature elsewhere. Was that due to the robbing of the oxygen from the air by the strata?

Mr. W. BOLTON SHAW (Manchester) said that it seemed to him that the main points on which it would be necessary for Dr. Harger to satisfy those responsible for the working of mines with regard to his suggestion were (1) whether the men could really work in an atmosphere denuded of some of its oxygen; (2) whether explosions and gob-fires would be done away with; and (3) whether his proposal could be carried out in actual practice. With regard to the first, namely, the physiological point, it did not seem to him that the evidence brought forward by the writer was altogether convincing. The atmosphere at a height of 9,000 feet was mentioned as being equivalent to 14 per cent. of oxygen; but he believed that he was correct in assuming that at that elevation the proportions were still the same, namely, 21 per cent. of oxygen and 79 per cent. of nitrogen; therefore, they were still dealing with a mixture in those proportions, whereas on the proposal of Dr. Harger, with 17 per cent. of oxygen in the mine, they would have a mixture of approximately 5 to 1 against 4 to 1. Was it safe to assume that the action of a mixture consisting of an active and a neutral agent was independent of the proportions of these two? It was also stated that animals had been able to live in an atmosphere having that reduced proportion of oxygen, but were they able to live in a state of continued activity? With regard to the third point, the possibility of carrying out the proposal in actual practice, his opinion was that a great deal of risk would be taken, and extremely strict precautions would have to be observed to prevent all possibility of danger from the flue-gases. The purification of the flue-gases would be effected by chemical means, and an artificial atmosphere, chemically produced, was not likely to

be very satisfactory. Such an atmosphere was used in the miners' rescue-apparatus, and experience showed that, even when the apparatus was working properly, a man began to show signs of distress after a comparatively short period of continuous breathing, while if anything went wrong with the apparatus it immediately became dangerous.

It seemed to him that to mix chemically-treated flue-gases with air to be breathed, was something analogous to turning purified sewage into a town's water-supply. A good many chemists would, no doubt, say that sewage could be purified to such an extent that the water coming from it would be absolutely pure, but he did not think that anybody would care for the notion of mixing it with drinking-water.

The PRESIDENT suggested that, as it was getting late, Dr. Harger should make a brief reply to the criticisms that had been expressed, and reserve his full answer for a future meeting. He (the speaker) did not know whether he clearly understood Dr. Harger to say that in explosions there was practically no burning at the working-faces. He had had to do with some explosions in which the men killed were not burnt at the coal-face. In certain other cases, however, both the coal-dust and the bodies of the men showed intense burning at the face. He understood Dr. Harger to say that this fierce burning was only found on the roads, but his own experience was that it occurred also at the face.

Dr. JOHN HARGER (Liverpool University) said that he would like to see a report of the full discussion before making any detailed reply. Mr. G. H. Winstanley had stated that he (Dr. Harger) had not had any experience underground. Certainly, he had not had much, but he had undergone the experience of losing himself and being overcome in a mine, and he was present at a gob-fire in a mine in South Yorkshire some time ago. He did not think that a 19-per cent. oxygen atmosphere would prevent gob-fires, but he did think that one of 17 per cent. would do so. He had been and was still trying to gather evidence on the point, and he would be grateful to anyone who would give him any information respecting gob-fires. He was engaged in research work on gob-fires, and had not got very far; but, from the evidence which he had gathered,

there were five or six distinct cases in which gob-fires had broken out after an increase in the ventilation. There was no doubt about that. And there were other cases that had been brought to his knowledge where gob-fires had started, and when the ventilation had been decreased they had gone out. He thought that the decrease in ventilation would be equivalent to a reduction in the quantity of oxygen, and he had every hope of being able to prevent gob-fires from breaking out by this reduction. He was almost certain to go to the South Yorkshire coal-field for 12 months to investigate the question, and he hoped to be able to find, not a cure, but the means of restricting such fires. What he said at present was, that with a 17-per cent. oxygen atmosphere, whether the fires broke out or not was a matter of indifference. They could never become dangerous. If there was 17 per cent. of oxygen in the air, no one need fear the fire; it could be left alone. It seemed to him that his critics thought that he was advocating a 17- or a 17½-per cent. oxygen atmosphere. He was, however, doing nothing of the sort. His proposition was that the oxygen in ordinary mines should be reduced to 20 per cent., and ½ per cent. of carbon dioxide added, which was the state of the atmosphere in which the men were working to-day at the coal-face. Let them start at that, and it would be time to reduce the oxygen to 17 per cent. afterwards. That explanation did away with a great deal of the criticism passed on the paper that evening. Hundreds of analyses had been taken, and they showed that the percentage of oxygen in mine air at the face was only 20. He proposed to reduce the oxygen to 20 per cent. in ordinary mines and add ½ per cent. of carbon dioxide, and to 19 per cent. of oxygen in the more dangerous mines, with ¾ per cent. of carbon dioxide. That was the proposition with which he would like to commence, and they would then be able to ascertain the results in respect both of respiration and explosions. He was, however, afraid that he personally could not undertake the larger experiments, unless the members of the Society came to his assistance by lending experimental shafts or doing work themselves. If they would not do either of these things, perhaps some other Society would. The matter was not new to the Home Office, as it was put before that department long before his paper was thought of. They had had the suggestion for 2 months, and if they were going to do anything, why not do it at once?

In answer to Prof. Dixon's question as to the danger of ignition of the gas-mixture from a blown-out shot, he had to say that the mixture could be exploded with an electric spark, but he fancied that anybody who wanted to wander about a coal-mine to try sparking effects with an induction-coil would be turned out. He thought that down at the coal-face, and in the returns where there was liability to get fire-damp, there should be no question about the use of electricity. It should not be employed at all there, for it was far more dangerous than any blown-out shot in causing the ignition of fire-damp or coal-dust.

With regard to Dr. Haldane's experiments with fire-damp, he did not know how Dr. Haldane made his fire-damp, for he found it a difficult matter to make pure methane in any quantity; and he fancied that those experiments were carried out with marsh-gas, as he himself had done, containing a large percentage of hydrogen, while the source of ignition probably was an electric spark.

In closing, let him say that he did not want his hearers to go away with the idea that he was advocating 17 per cent. of oxygen. Let them take 20 per cent. for the ordinary mine, and 19 per cent. for the dangerous mine, and start with that. It would be quite sufficient, and would do away with dust explosions. As to the signs of burning in the Hulton case, undoubtedly there they had an ignition, not of coal-dust, but of a mixture of coal-dust and gas. His remarks about ignitions not originating in the face applied only to coal-dust, for never in normal working did one get a sufficient reduction of the oxygen to prevent fire-damp explosions. Such occurrences as the lights going out in a great stretch of the mine were extremely rare.

He (Dr. Harger) wished to express his indebtedness to the authorities of Liverpool University for facilities granted him for carrying out his experiments in the Inorganic Chemical Laboratories of the University.

THE MANCHESTER GEOLOGICAL AND MINING SOCIETY.

GENERAL MEETING,

HELD IN THE ROOMS OF THE SOCIETY, QUEEN'S CHAMBERS,

5, JOHN DALTON STREET, MANCHESTER,

MARCH 12TH, 1912.

MR. GEORGE B. HARRISON, PRESIDENT, IN THE CHAIR.

Mr. CHARLES D. TAITE read the following paper on "The Lancashire Electric Power Company's System, and its Application to Lancashire Collieries":—

THE LANCASHIRE ELECTRIC POWER COMPANY'S SYSTEM, AND ITS APPLICATION TO LANCASHIRE COLLIERIES.

By CHARLES D. TAITE, M.I.E.E.

The company carries on its operations under three Acts of Parliament, which were obtained respectively in 1900, 1904, and 1906; and the powers conferred by the respective Acts are briefly:—

1900 Act.—Power to supply electrical energy in bulk to local authorities or companies authorized to supply electrical energy within specified districts.

1904 Act.—Power to take a transfer of electric lighting orders or undertakings.

1906 Act.—Power to supply electrical energy to users of power.

The area in which the company is authorized to supply electricity is described in the 1900 Act as being the County of Lancaster, except that part of the county which lies to the northward of the River Ribble, and the county boroughs of Manchester, Salford, Liverpool, Bootle, and Stockport, and so much of the county borough of Bolton as lies within 2½ miles of the existing town hall.

The bulk of the company's business has been obtained under the 1904 and 1906 Acts. A large number of electric-lighting orders have been transferred to the company by local authorities, and it is mainly in those areas the names of which are shown underlined on the map (Fig. 1, Plate IV.) that the company's consumers are situated.

Power-Station.—The company's power-station was started in October, 1905. In several respects it was a pioneering station. Thus the whole of the plant was turbine-driven, and vertical turbines were adopted: all the four machines were identical, and were

each of 1,500 kilowatts capacity. The generating pressure (10,000 volts) was the highest used in the county, the municipal stations having adopted 6,500 volts as their standard; and a considerable length of the main feeders was erected in the form of bare copper conductors. Every one of the innovations has been justified by results, the turbine-station having a most satisfactory record from the point of view of continuity and regularity of supply. The high voltage has given no trouble either in the station or on the mains, and it has enabled a much greater distance to be traversed than would have been possible if one of the lower standards had been adopted. The necessities of the case required a high voltage, as will be readily understood when it is mentioned that the Radcliffe station is already supplying places so far apart as Ramsbottom, Swinton, and Hindley, while an extension through Ashton-in-Makerfield to Earlstown, a distance of about 10 miles, is projected.

As for overhead mains, they are now the rule rather than the exception: they are equally as reliable as underground cables, and are roughly a third of the cost.

The power-station has recently been extended, and a 2,500-kilowatt turbo-generator set has been installed, while the older plant has had its output improved some 30 per cent. by the provision of forced ventilation for cooling the generators, the turbines having been designed very liberally. The total capacity of the plant is now, therefore, over 10,000 kilowatts, and a further set of 3,500 kilowatts has been placed on order to cope with the rapidly increasing load. With this addition, which will be completed in the autumn, the plant capacity will be 14,000 kilowatts, or, roughly, 20,000 horsepower.

The items of interest at the station, apart from those mentioned above, are as follows:—

(*a*) The compact arrangement of the station.

(*b*) The large boiler-unit adopted for the extensions, this being rated at 30,000 pounds of steam per hour, but capable in case of emergency of an output considerably in excess of that figure.

(*c*) The ferro-concrete chimney.

(*d*) The coaling arrangements.

With regard to (*a*), the present engine-room now measures 152½ by 48½ feet, and when fully equipped will contain seven

generating sets, totalling 17,500 kilowatts, or approximately 25,000 horsepower. The boiler-houses, two in number, are built at right-angles, and at present contain three rows of boilers; a fourth row will be added when the seventh set is installed.

The ferro-concrete chimney was erected last year, and is believed to be the first large chimney of its type in Lancashire. The reinforcement is in the form of steel tees measuring $1\frac{1}{4}$ by $1\frac{1}{4}$ inches by $\frac{3}{16}$ inch, arranged vertically, and $\frac{1}{2}$-inch bars arranged horizontally. The form of construction adopted enabled the chimney to be built rapidly, and there is every indication that the work is sound in all respects.

One of the most interesting features of the station is undoubtedly the design of the coaling arrangement. Full advantage has been taken of the fact that the boiler-house floor is situated some 70 feet below the bank on which the railway-siding is laid out, which enables the coal to be conveyed by the action of gravity from the railway-wagons to the boiler-house bunkers. The coal is dropped through the bottom doors of the wagons into a hopper holding some 20 tons, and immediately beneath this hopper the track of the gravity railway commences. This track, which is about 300 feet long, is carried by a series of tressels to the tops of the storage-bunkers situated above the boilers, and has a fall towards the boiler-house of 1 in 36.

A special truck, which holds about 25 hundredweight, is filled with coal from the hopper, and started by hand down the incline. The truck gathers speed rapidly, and just before the end of its journey is brought into contact with an arrangement which gradually brings it to a standstill, and at the same time stores up the power expended in so doing. At the place where it stops a trip is arranged, whereby the coal is discharged into the bunkers below; the empty truck being relieved of its weight, and receiving its impetus from the power stored on its downward journey, is sent up the slope to receive another load. The whole operation takes approximately 2 minutes, which is equivalent to handling $37\frac{1}{2}$ tons of coal an hour.

The arrangement of stopping the truck and sending it back up the inclined track is shown in Figs. 2 and 3 (Plate V.). A long wire rope attached at *F* is taken half a turn round a moveable pulley *B*, back round a fixed pulley *C*, along the track to a fixed pulley *D*, again half a turn round *B*, and attached at its

other end at *G*. It will be seen that any movement to the rope which lies along the track between *C* and *D* will produce a movement of the moving pulley *B* along its special track; but, in moving, this pulley has to raise the large weight which is shown pivoted at *A*. An adjustable clamp *H* is fixed to the rope, with which the truck *E* coming down the slope comes into contact. Owing to the arrangement of the weight, pulley *B* starts moving with practically no load on it, and the load is introduced gradually until the maximum effect is reached at the point where the truck stops. At this point a lever on the truck *E* comes into contact with a lever fixed to the track at *J*, causing the doors to open and the contents to empty.

The weight, even if the truck was not emptied, has now sufficient energy stored in it to send the truck back for a considerable distance up the track; but, being relieved of the weight of coal, the energy is sufficient to send the empty truck back to the exact spot from which it started.

The clamp *H* and the tripping lever *J* can be placed in any position along the track, wherever it is desired to empty.

The station is situated on the banks of the River Irwell, the water of which is used for condensing. The amount of water required by each of the sets originally installed is about 125,000 gallons per hour, or an aggregate of 500,000 gallons per hour when the four sets are running together. The river-water is one of the most serious difficulties with which the company has had to contend, because at storm times in the autumn a tremendous quantity of leaves, grass, and other vegetable matter is brought down by the flood-water; and although elaborate screens have been provided, it is a matter of great difficulty at such times to prevent them from becoming choked. Various proposals have been made to overcome the difficulty, but most of them on careful examination have been shown to be impracticable, and a man with a brush is still found to be the best remedy.

The electric power leaves the generating station by means of overhead wires carried on A-poles, there being two feeders and therefore six wires to each pole. The feeders are carried in duplicate throughout the whole system, the present extent of which is shown on the map (Fig. 1, Plate IV.), and each consumer is given a duplicate supply. This is necessary, not on account of faults on the cables, which as a matter of fact are very rare, but

owing to the time required in making a joint on the feeders when a new consumer is connected up. A tee-joint usually takes about 24 hours, so that a second cable is a necessity.

As the electrical energy is transmitted at 10,000 volts, it has to be transformed to a lower voltage in order to render it suitable for consumers. The transforming plant and the switches for controlling it are supplied by the company; but provision is made for the operation of the switches by the consumer from the low-tension chamber, and he thus has under his control the supply from the two feeders.

A typical sub-station is shown in Figs. 4 and 5 (Plate V.), from which it will be seen that the building (which is supplied by the consumer) measures 25 by 17½ feet overall, and is divided into two portions, used respectively for the high- and the low-tension supply. The cost of the building is usually about £75. Fig. 5 (Plate V.) shows a plan of the equipment, which is of the simplest possible description. From the oil-switches all the conductors, both high-tension and low-tension, are bare, placed, of course, well out of reach. The company has adopted this arrangement, not only on account of reduced cost, but also on account of safety, for everyone knows that a bare copper conductor when alive is not a thing which it is advisable to handle.

The aggregate horsepower supplied to collieries in Lancashire by the company is at present about 3,000, and this will shortly be increased by work in hand to about 4,000. The present annual consumption by these collieries is at the rate of about 4,000,000 units. For some reason Lancashire has been slower to adopt electrical methods than other colliery districts. In the Newcastle district the three power companies are supplying electrical energy at the rate of over 55,000,000 units per annum for colliery purposes. In South Wales 12,500 horsepower is being taken from the power company's mains, and a further 3,500 horsepower is contracted for. In the Clyde Valley district about 8,500 horsepower is either connected or contracted for; while in Yorkshire the present connexions are 4,000 horsepower, with an additional 2,000 horsepower contracted for; and included in these supplies are three winding-gears, while three more are to be installed. Possibly the age of the pits has something to do with the backward electrical condition of Lancashire collieries; but it may be pointed out that, where

coal is difficult to win, the most modern methods of working are essential, in order that the cost of dealing with the coal may be kept at the lowest possible figure.

The uses to which the company's electric power is put by the various collieries are manifold; and, by the courtesy of the Clifton and Kersley Coal Company, the writer is able to give in Table I. an interesting list of the motors which they have installed at their collieries, together with the purposes for which they are employed:—

TABLE I.—ELECTRIC MOTORS INSTALLED AT THE COLLIERIES OF THE CLIFTON & KERSLEY COAL COMPANY, LIMITED.

Application.	Horsepower.
OUTWOOD WORKSHOPS.	
Driving shears	7½
Fan for smiths' fire	6
Driving fitters' shop	10
Fan for pick-sharpener	1½
OUTWOOD SURFACE.	
Driving screens	18
Air-compressor condenser	11
Induced draught for Bettington boiler	20
Pulverizer to Bettington boiler (temporary stand-by plant)	60
Coal-crusher for boilers	11
Mechanical stokers	10
Motor-generator for charging lamps	1½
OUTWOOD WASHERY.	
Driving coal-washery	100
Driving coal-washery pump	100
Capstan for trucks	60
Air-compressor	25
Wagon haulage	18
Centrifugal pumps (60 gallons per minute)	9
Hydraulic pumps for wagon-tip	9
OUTWOOD UNDERGROUND.	
Three-throw pump, No. 2 Pit (100 gallons per minute, 714 feet)	35
Three-throw pump, No. 4 Pit (50 gallons per minute, 1,500 feet)	35
Also one electric heater, 7·9 amperes, which raises air-temperature to 84°-97° Fahr.	
KERSLEY.	
Three-throw pump, No. 2 Pit (282 gallons per minute, 940 feet)	100
NEWTOWN.	
Driving air-compressor (2,000 cubic feet per minute)	360
Centrifugal pump	6½
Total horsepower	1,013½

It will be noticed that electric motors are used for a great variety of purposes at Outwood Colliery, but no coal-cutters are

yet installed. The colliery is also electrically lighted throughout, and there is an interesting application of electric heating. Some trouble was experienced with a compressed-air haulage-engine of 250 horsepower, owing to freezing at the stop-valve; but the trouble has been entirely overcome by installing an electric heater, which raises slightly the temperature of the air on its entering the engine. The consumption of the heater is only 5 kilowatts, and when the engine is stopped the heater is put out of action. The total annual consumption by the Clifton & Kersley Coal Company is about 2,200,000 units a year.

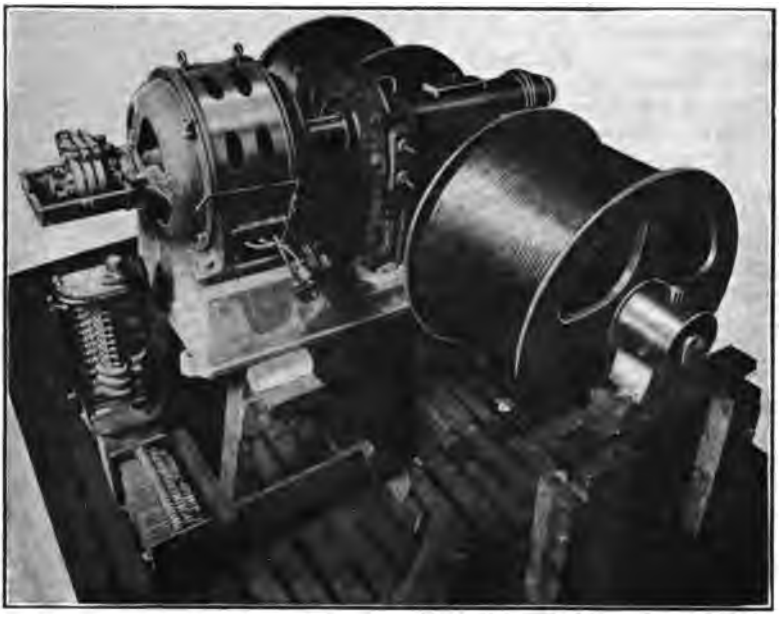


FIG. 6 - DOUBLE-DRUM 45-HORSEPOWER HAULAGE-MOTOR.

One of the oldest consumers of the power-company is the Westhoughton Coal & Cannel Company, and by the courtesy of Mr. J. P. Winstanley, the manager of the colliery company, the writer is able to give in Table II. some figures of a test carried out by him at the colliery, which throw some light on the relative efficiency of electricity and compressed air for coal-cutting purposes; and the same relation between these two forms of power would doubtless be obtained in haulage, pumping, and other work about a colliery:—

TABLE II.—TESTS TAKEN ON COAL-CUTTERS BY MR. J. P. WINSTANLEY AT WESTHOUGHTON COLLIERY, JANUARY, 1912.

(1) *Gillott Compressed-air Coal-cutter (Disc Type).*

Alley Maclellan water-cooled single-stage air-compressor on the surface, for dealing with 700 cubic feet of free air per minute at a pressure of 60 pounds per square inch.

Driven by a 140-horsepower Westinghouse three-phase motor.

Compressor when driving above the coal-cutter working at about 75-80 per cent. of the full load.

Coal-cutter working 690 yards away from the compressor.

Width of cutter, 4½ inches.

No. of Test.	Hours Cutting.	Yards Cut.	Under-cut.	Total Square Yards Cut.	Total Units.	Units per Square Yard.	Square Yards per Hour.
			Feet.				
1	15	155	2½	129	610	4·72	8·60
2	11½	150	2½	125	510	4·08	10·90
3	14	162	2½	135	590	4·37	9·65
4	13½	158	2½	132	590	4·47	9·80
Totals and averages	54	625	2½	521	2,300	4·41	9·74

(2) *Hopkinson Electrical Coal-cutter (Chain Type).*

Driven direct by a 25-horsepower three-phase motor.

Coal-cutter working 1,430 yards from the point where the current is metered.

No. of Test.	Hours Cutting.	Yards Cut	Under-cut.	Total Square Yards Cut.	Total Units.	Units per Square Yard.	Square Yards per Hour.
			Feet.				
1	6½	64	3½	74·6	104	1·40	11·5
2	6	45	3½	52·5	43	0·82	8·7
3	6¼	72	3½	84·0	105	1·25	13·4
4	5¾	56	3½	65·3	85	1·30	11·4
Totals and averages	24½	237	3½	276·4	337	1·19	11·3

It should be explained that the electric motor driving the air-compressor is supplied from the company's sub-station at the pit-top, and that the coal-cutter is supplied from the same sub-station, but in the latter case the current has fully 1½ miles to travel before being utilized. It will be observed that the amount of electrical energy per square yard cut by the com-

pressed-air coal-cutter is just over 3·6 times that taken by the electric coal-cutter, and that the latter did 17 per cent. more work per hour, assuming the conditions to have been the same in both cases. The tests show clearly that a very substantial saving may be effected by substituting electrical energy for compressed air for practically all the purposes for which compressed air may be used in a pit.

Through the courtesy of the Ladyshore Coal Company, the writer is enabled to give in Table III. a few figures relating to a double-drum haulage motor of 45 horsepower, which was installed and is supplied with electrical energy by the power company. The plant (Fig. 6) is of some interest, as the motor is geared to the drums by worm-gears running in oil. This drive is practically noiseless, is compact, and has proved very satisfactory in operation.

TABLE III.—TESTS TAKEN AT LADYSHORE COLLIERY ON A WINDING-PLANT FOR A DOWN-BROW, 576 YARDS DOWN, WITH AN INCLINATION OF 1 IN 2½.

For the week ending.	Units.	Tons of Coal.	Tons of Dirt.	Tons of Water.	Total Tons	Units per Ton.
December 26th, 1911 ...	370	172½	27	11	210½	1·76
January 2nd, 1912 ...	305	140½	25	7	172½	1·77
,, 9th, 1912 .	470	212½	30	8	250½	1·88
,, 16th, 1912 ...	530	220	54	0	274	1·93
Totals and average ...	1,675	745½	136	26	907½	1·84

It will be seen that this works out at an average of 1·84 units per ton. No allowance, however, has been made for winding men and materials.

It may be mentioned that one advantage of electric hauling is that automatic circuit-breakers can be provided which will at once operate if the tubs come off the rails, and a powerful electric brake is automatically applied. In this way damage to the roads is prevented.

Three collieries now rely on the company for their ventilation, and there are a large number of pumps connected to the supply, the majority of which only run at night, and thus obtain

The Institution of Mining Engineers
Transactions 1911-1912.

To illustrate Mr. Charles D. Taite's Paper on "The Lancashire Electric Power company's System," etc.

VOL. XLIII. PLATE IV.

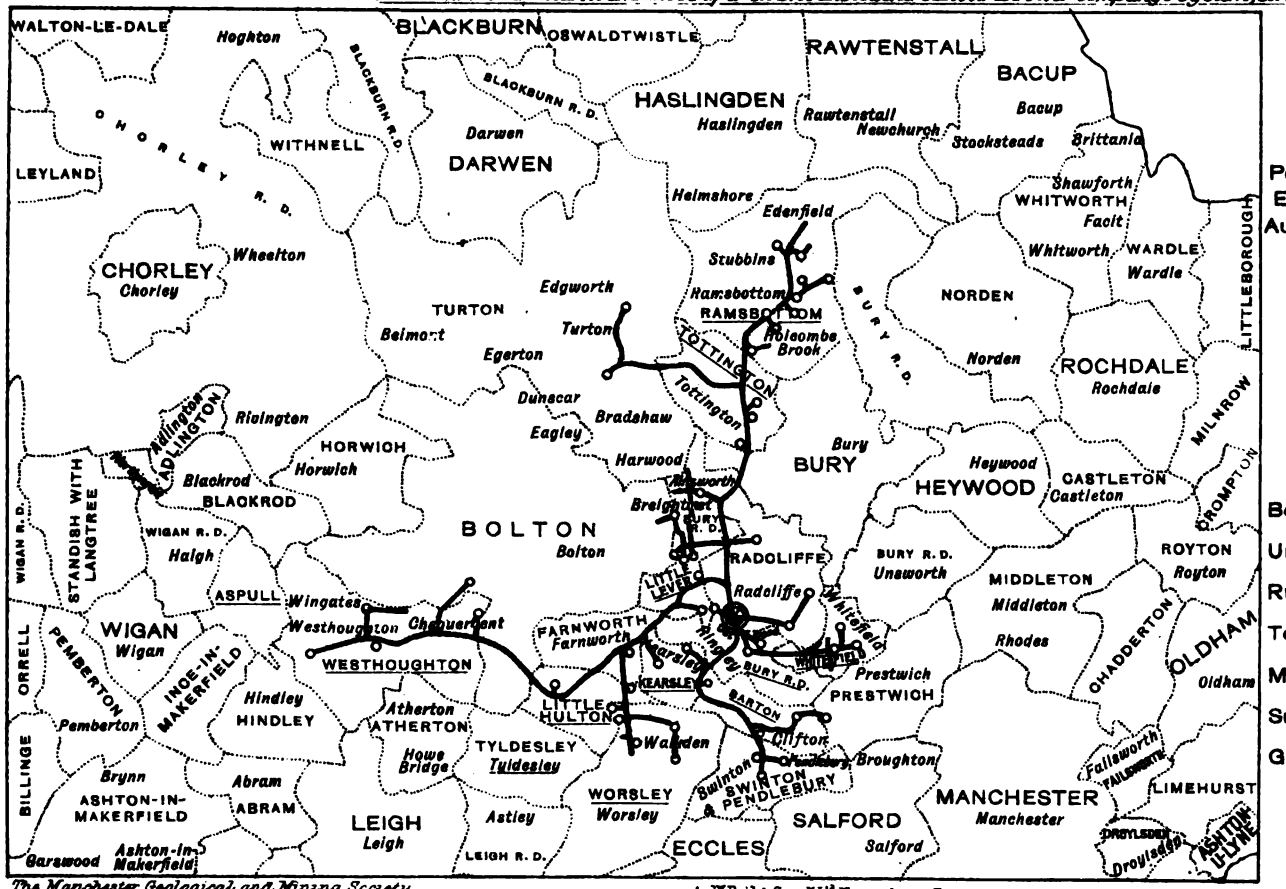


FIG. 1.—MAP SHOWING A PORTION OF THE LANCASHIRE ELECTRIC POWER-COMPANY'S AUTHORISED AREA OF SUPPLY.

REFERENCES.

BOROUGHS - -	BURY
URBAN DISTRICTS -	ABRAM
RURAL DISTRICTS -	BARTON
TOWNS AND VILLAGES	Brynn
MAINS LAID - -	———
SUB-STATIONS - - -	o
GENERATING STATION	⊗

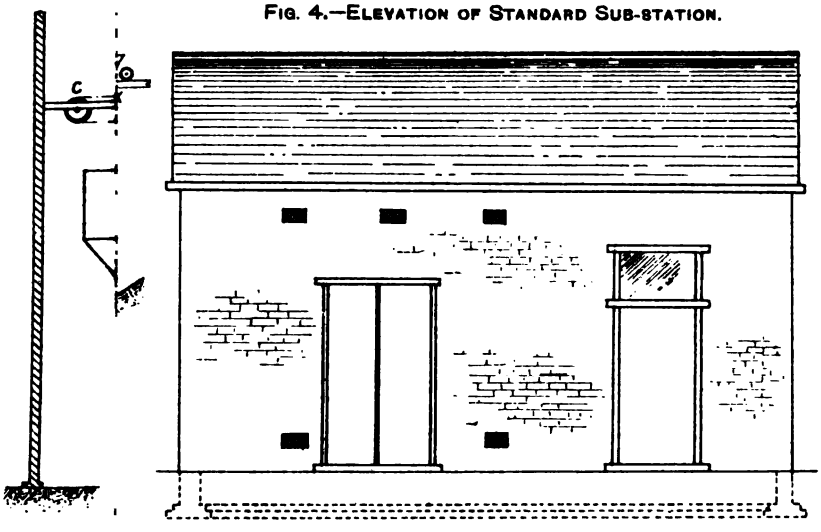
The Manchester Geological and Mining Society
Transactions 1911-1912.

And.r Reid & Comp.y Ltd. Newcastle upon Tyne.

VOL. XXXII. PLATE XVIII.

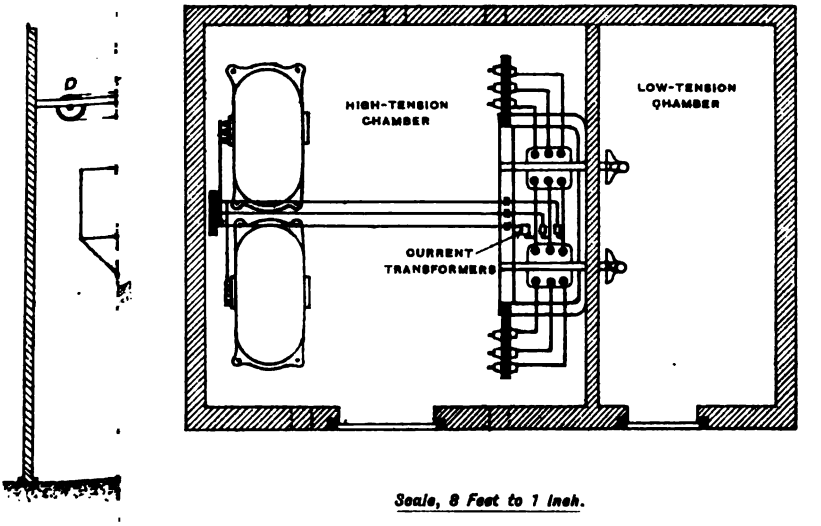
FIGS. 4 AND 5.—TYPICAL SUB-STATION ON THE MAINS OF THE COMPANY.

FIG. 4.—ELEVATION OF STANDARD SUB-STATION.



Scale, 8 Feet to 1 Inch.

FIG. 5.—PLAN OF STANDARD SUB-STATION.



Scale, 8 Feet to 1 Inch.

the benefit of a specially low tariff. The largest squirrel-cage motor at present connected to the company's system for colliery purposes is one of 240 horsepower for pumping, and, despite the heavy starting current taken by the motor, the operation of starting it has no undue effect on the rest of the company's system. It is most improbable that squirrel-cage motors of this size could be used if the colliery generated its own power, as the effect of the heavy current at starting would be too severe. It is very usual on the mains of even large corporations to limit the use of this type of motor to about 50 horsepower.

In conclusion, the writer may say, with regard to the policy of the company, that for financial reasons it was obviously impossible at the outset to instal distributing cables over the whole area covered by the company's statutory powers, and accordingly the supply has been restricted to an area which may roughly be stated to be 20 miles long by 10 miles wide. It is, however, by no means the intention of the company to restrict their operations permanently to this district. On the contrary, the policy is to extend in any direction from which a reasonable return on the capital outlay may be anticipated, as it is recognized by those responsible that it is only by operating on a very large scale, and by so doing to distribute the standing charges over a big output, that electrical energy can be supplied for all purposes at the lowest possible rates.

Mr. Robert Winstanley (Manchester), in moving a vote of thanks to Mr. Taite for his most interesting paper, said that a colliery with which he was connected was the first to make use of the electrical power supplied by the company. To do this, the power company had to put down about 10 miles of cable. The company also installed the whole of the machinery, transformers, cable, and shafting. The plant had been at work for about 6 years, there had never been a serious failure, and never an accident to any person. Mr. Taite had remarked that the number of old collieries in Lancashire was in some way responsible for the slow extension of the use of electricity from this company. His own view was that electricity should commend

itself to those collieries that were not expected to last more than 7, 8, or 10 years, and where it was not thought worth while to put down new boilers and engines. In such cases the owners had an opportunity of getting all the power that they wanted without having to purchase new boilers, new engines, etc. That was what had been done at the colliery to which he had referred, and he thought that the use of electricity from power-stations would increase in the future.

Mr. VINCENT BRAMALL (Pendlebury) seconded the motion, which was carried.

Mr. JOSEPH DICKINSON (Pendleton) said that Mr. Taite had given them some statistics as to the amount of coal used for a number of boilers, and the extension of power in different parts of the district. Could Mr. Taite tell the members, concisely, what was the power necessarily expended in changing the steam power into electricity for applying electric power? In other words, what was the percentage of power utilized in applying it when so converted to colliery uses and to tram services such as were running in the streets?

Prof. W. BOYD DAWKINS (Manchester) asked how far electricity could be carried economically from the central generating works. He believed that in America the area of supply was being continually enlarged.

Mr. HUGH V. HART-DAVIS (Pendleton) spoke of the effect of the electric heater. It raised the temperature of air to 87° to 97° Fahr. This was sufficient to prevent the pneumatic haulage-engine from freezing, and was a very great economy. At Kersley Colliery there was a three-throw pump which raised 282 gallons of water per minute to a height of 940 feet. A test showed the efficiency to be 74·5 per cent. over all, which he considered good.

He thought that one of the advantages of taking power from a power company was the use of squirrel-cage motors, to which Mr. Taite had referred. Mr. Robert Nelson, in the paper which he read before The Institution of Mining Engineers, said: "Squirrel-cage motors can be used for almost every service,

and they should undoubtedly be used wherever possible."* He (Mr. Hart-Davis) had found that such was the case, and he was using them for many purposes. Squirrel-cage motors and slip-clutches had been improved, and he believed that they could be used for haulage.

If collieries were going to employ electric power for driving fans, they would require some guarantee against failure of supply, and he hoped that the Lancashire Electric Power Company would at some future date be able to give this guarantee, and instal another, or more, stations in the county. He also hoped that the company would do as sister companies were doing in the north, namely, utilize the waste-heat and exhaust-steam from various concerns, and supply power at a much lower rate. When the members realized that at many collieries some 2 horsepower was wasted continuously in the way of exhaust-steam for every ton of coal brought to the surface, they would see that there was a large amount of energy still available.

The collieries with which he was associated had taken current from this company for 3 years, and had found it extremely satisfactory: electric lamps, for instance, had a longer life than when they had their own supply at the colliery.

Mr. GEORGE J. RIDYARD (Tyldesley) referred to the comparison which was made between compressed-air and electric coal-cutting, and asked whether Mr. Taite or Mr. Winstanley could give further particulars, so that the members could judge of the fairness of the comparison. The author said "assuming that the conditions were the same," which was assuming a great deal. He did not think, so far, at least, as many Lancashire mines were concerned, that electric coal-cutting was a practicable proposition at present; but where it was, the figures given were certainly very impressive, especially as the electric cutter was holing 1 foot deeper than the compressed-air cutter.

Mr. JAMES P. WINSTANLEY (Westhoughton) stated that the compressed-air cutter was working in the Three-Quarter Mine, which was 19 inches thick, and in the particular tests referred to the machine was cutting in the coal about 2½ feet deep. As a rule the cutting was done in the under-clay, but in order to put the

* "Electricity in Coal-mines," by Robert Nelson, *Trans. Inst. M.E.*, 1909, vol. xxxvii., page 475.

tests with the two machines on a level, they had cut in the coal. In the case of the electrical machine, the cutting was again in the coal, but was 3½ feet deep as against 2½ feet, as the coal itself was very much harder, both of which factors—the deeper cutting and the harder nature of the coal—being in his opinion very much against the electrical machine. He was afraid that he could not quite agree with Mr. Ridyard as to the relative merits of the two machines, for his own opinion was that the superiority lay with the electrical machine.

With regard to upkeep, his opinion was that there could be no comparison between the two cutters. For every breakdown that they had with the electric machine working in the mine they had five in the case of the compressed-air machine. The overhauling of the electrical machine was carried out about once every 3 months, whereas the compressed-air machines had to be brought out at least once every 3 or 4 weeks.

Mr. G. W. Cook (Manchester) said he could support all that Mr. Taite and Mr. Winstanley had said in regard to the electric coal-cutting machines. He had seen both kinds of machines in operation, and the one at Westhoughton was the best that he had seen in Lancashire, Yorkshire, Warwickshire, or Scotland.

Mr. Vincent Bramall (Pendlebury) asked whether any allowance was made for the energy used in compressing the air. Apparently they were doing the work in two stages, and taking advantage out of one. First the air was compressed by electricity, and then the compressed air was used, so that there was a double loss. If the air were compressed direct, there would only be half the loss. Further, there was the point whether the Hopkinson coal-cutter was not much more efficient, requiring less power, than the Gillott machine.

Mr. Leonard R. Fletcher (Atherton) said that it seemed to him that this was not a matter of comparison. There was a Hopkinson machine against one of another make, and for the sake of comparison there ought to have been the same machines in either case, namely, both Hopkinson or both Gillott. He did not quite understand the figures that had been given. The conditions seemed to be so different, and the cases did not seem at all parallel.

Mr. C. H. Ryley (Manchester) said that the comparison with regard to the coal-cutters gave so surprising a result that it was a pity that equally interesting figures had not been obtained from other machines. At the present moment there was undoubtedly some prejudice against electric coal-cutters, and it would therefore have been interesting to have had similar comparative figures with regard to haulages and pumps; also the comparative cost of electrical power for hauling, as against the old-fashioned rope-driven haulage, which was very much in evidence in a good many of the old mines in Lancashire. Referring to the 45-horse-power haulage-motor mentioned in the paper, he thought that it was rather a departure from the ordinary custom to fit a worm-drive to haulage-gear in place of the usual spur-wheel drive, and he would like to know how the two types worked out with regard to cost. Of course, in putting down any electrically-driven machinery, it was chiefly a question of cost; and if the price of the worm-drive was in any way comparable with that of the spur-wheel drive, the former had in other respects many advantages, especially in the small amount of space that it required. Worm-gearing was now so efficient, and compared so well with spur-gearing, that if Mr. Taite could supply figures on that point, and also as to the comparative strength, they would no doubt prove of interest to many present.

Mr. George S. Caldwell (Westhoughton) said that it was not quite a question of comparison of coal-cutting machines, for in many cases the choice did not lie with the manager or other official; it lay with the mine itself. If all coal-mines were thoroughly safe for electric power, he believed that compressed air would be eliminated and give place to electrical energy. He therefore submitted that it was hardly fair to compare the two powers from a monetary point of view. The important question was whether it would be safe to use electricity under certain conditions.

Mr. Vincent Bramall stated that he might have been under a misapprehension when making his earlier remarks. Was the compressor to which he referred driven by steam? He took it that the air was first compressed by electricity.

Mr. J. Drummond Paton (Manchester) referred to the ease with which the coal was transferred to the boilers. He had seen the power-station, and had noticed the difficulty in handling the ashes. He would like to know to what extent the ease in one case was counterbalanced by any difficulty in the handling of the ash; also, as a strong claim for efficiency and economy had been made in the paper, and as electrical transmission was a vital question to mining engineers, he would like to ask Mr. Taite's opinion on the relative economy and efficiency of aluminium as compared with copper conductors.

Mr. G. G. L. Preece (Manchester) thought that the most interesting part of the paper was that which stated the amount of electric horsepower supplied by various other power-companies in England and Wales. The Lancashire supply could not compare with that of Newcastle-upon-Tyne. Mr. Taite said that possibly the age of the pits in Lancashire had something to do with that. Mr. Taite no doubt thought that this statement might induce some of the Lancashire colliery engineers to state why they did not adopt electric power. He agreed with Mr. Taite that there was no doubt of this backwardness; and it behoved the Lancashire collieries to look seriously into the matter, or else they might rue it later on.

There was a great advantage, however, with those power companies where waste-steam and heat from collieries could be utilized, and, further, in many cases it paid the collieries to utilize these waste-products and generate the electric power themselves. He saw little prospect of Mr. Taite increasing his colliery load at the Lancashire Electric Power Company's station, unless he was able to obtain facilities for the erection of waste-heat stations to run in parallel with his ordinary supply.

The President (Mr. George B. Harrison) said that one thing that occurred to him had reference to the North of England collieries and the observations made as to the utilization of waste-heat. He knew the district very well in years gone by, and could therefore understand why there was greater opportunity for power companies there than in Lancashire. In the North of England nearly every colliery for many miles around had its coke-ovens, and that gave the electric-power companies an

advantage. There was, he thought, only one colliery company in Lancashire within the range of this power company that had coke-ovens on a large scale, and the waste-gas was utilized in the district for lighting purposes.

Mr. JOHN GERRARD (H.M. Inspector of Mines, Worsley) said that Mr. Taite had given them an admirable paper. He was glad to see that the Lancashire Electric Power Company required to extend their area of usefulness. He held the opinion that there was a large field for the use of electricity in connexion with mining. This was proved by the numerous splendid installations at mines in the United Kingdom, on the Continent, in Canada, and in America. In this discussion much had been said on the question of coal-cutting by electricity; but surely this was only a portion of the field. Those who preferred compressed air for power at the coal-face had excellent reasons for so doing; he would not endeavour to persuade them otherwise, and it was quite feasible to use electricity to compress air to be carried forward to the face. He agreed with Mr. Robert Winstanley that an old-established colliery would largely gain by installing electricity. To continue losing money on old boilers, old engines, old plant, etc., was hardly wise.

Mr. SYDNEY A. SMITH (Manchester) said that he would be glad if Mr. Taite could give them a few figures as to the actual cost, the price per unit, or the price at which the company would deliver power per annum. With regard to the question of the price of electric power in other countries, he had had something to do with several hydro-electric power-stations abroad. In Sweden electric power was generally produced by water, and last year in that country he had arranged a contract with a power company to supply electric power at high tension to a mine with which he was associated. The power company agreed to a continuous supply at the mine of 500 horsepower throughout the day and night at a price which worked out at about £1,666 a year, or £3 6s. 8d. per horsepower per annum, and they could take up to 1,000 horsepower at the same rate.

Mr. C. D. TAITE (Manchester) thanked the members who had spoken for their very kind comments on his paper, and in particular Mr. Gerrard, who had been very appreciative in his

remarks as to the advantages of electric driving. One felt that those remarks, coming from Mr. Gerrard, who was responsible to the Government for the safe operation of collieries, were very encouraging.

Taking the points in the order in which they had arisen, there was, first of all, the question concerning the efficiency of the system. What was the percentage of power actually used in relation to that which was sent out from the station? In their case the loss was 15 per cent., and he did not think it possible to reduce the loss below that point on such a system as theirs. Most of the loss was not in transmission, but in the magnetizing current taken by the transformers on the system, which were in use day and night, although the actual power issued through the transformers was probably only required on an average for 8 or 9 hours a day; the transformer losses, however, were continuous.

As to the distance to which their electric power could be carried, they had not reached the limit of the economical transmission from one generating station. As he had pointed out, the total loss was 15 per cent., and of that amount probably at least 10 or 12 per cent. was due to the transformers, and only about 3 or 5 per cent. to transmission loss.

Then there was the question of the utilization of waste-heat and exhaust-steam. That had been answered by the President, who had pointed out that in Lancashire there was practically no scope at present for the utilization of waste-heat, there being no coke-ovens from which any heat was available. There was, of course, exhaust-steam, but few of the Lancashire collieries were of sufficient size to warrant the big capital-cost involved in putting down exhaust-steam plant. His company were prepared to investigate any particular case where there was exhaust-steam available, with a view to putting down an exhaust-steam apparatus at the colliery and linking it up with the company's general system. The company thought that this would be a much more satisfactory method for the colliery-owners than putting down their own exhaust-steam plant and having that only to rely upon. If the company's suggestion were adopted, then, in case of a breakdown of the exhaust-steam plant, the company's system would be available for supply.

The coal-cutting figures were simply given as an indication

of what economies might be expected by utilizing electric power instead of compressed air, not only for coal-cutting, but for other purposes. The fact that one of the air-compressors at Westhoughton was driven by a motor did not in any way affect the comparison, because, whether the compressor was driven by a motor or by a steam-engine, the loss would be practically the same. For instance, the motor would have an efficiency of probably 90 per cent., and that of the steam-engine would be certainly no greater, so that in both cases the prime mover of the air-compressor would have the same efficiency. Of course, the electric driving of an air-compressor, as in the case under notice, lent itself to making a test of the actual power required by air operation for coal-cutting or for a haulage plant. He would like to have carried the comparison further, and been able to tell the members what saving there was by replacing a compressed-air haulage plant by an electric plant, but that would be a very much bigger matter, a much more difficult calculation to work out, and he had not had the opportunity of doing so.

With regard to the haulage plant at Ladyshore Colliery, the worm-gear had a treble-thread worm gearing with a 53-toothed wheel. The efficiency of the gear was guaranteed to be not less than 90 per cent., and the makers claimed that in all probability it would amount to 92 or 93 per cent. after working for a few weeks. A double-reduction spur-gearing would certainly not have a higher efficiency than the above. So far as the factor of safety was concerned, the pressure on one tooth working at full load was approximately 1,500 pounds, and the ultimate rupture load was about 50,000 pounds, so that a factor of safety of over 30 was obtained. It was probably unnecessary to point out that it was not advisable constantly to overload worm-gears despite the high factor of safety, as the polished surfaces of contact of the worm-wheel would under such conditions rapidly deteriorate, with a consequent considerable reduction in efficiency.

On the question of cost, from offers which the author had received from time to time, a high-class worm-gear usually appeared to cost about 10 per cent. more than a high-class double-reduction gear.

Mr. Paton had raised the question of handling the ashes at the power-station. Of course, those ashes had to be raised from the floor of the boiler-house, or rather the basement beneath the

boilers, and that work was done by an electric motor on a small inclined railway. He had given no details of the actual consumption of power, but he could say that it was extremely small; and there was no difficulty whatever in dealing with the ashes. High-class coal was used, and therefore the amount of ash was small.

As to the charges for electric energy, those depended entirely upon the uses to which the power was to be put. Thus, if the power were to be used for night pumping, for instance, between 6 p.m. and 6 a.m., a very low rate indeed would be charged. If the power were for ventilation, running day and night, the price would also be very low, but perhaps not quite so low as for night pumping, the reason being that the great bulk of the power from the generating station was required for day use, and the company naturally were anxious to obtain consumers to take the power when nobody else wanted it. Again, for haulage work the price was naturally higher, because of the very intermittent nature of the load, making it a much more difficult type of load to deal with than in the case of pumping or ventilation. The basis of prices on which the charges had been fixed was £4 per kilowatt, plus a farthing per unit taken. The company had found great difficulty in getting people to appreciate and understand thoroughly the meaning of this tariff, and one generally had to convert it into a flat rate of so much per unit.

The President had suggested that possibly some members of the Society might like to visit the power-station again. He could only say that it would give him very great pleasure (and he was sure his directors also would be glad) if the Society as a body, or any individual members, paid a visit to the station, as since the members' last visit the station had been considerably enlarged. The very latest type of steam-turbines and a second coaling railway had been added.

THE MIDLAND COUNTIES INSTITUTION OF ENGINEERS.

GENERAL MEETING,
HELD AT UNIVERSITY COLLEGE, NOTTINGHAM,
MARCH 2ND, 1912.

MR. J. P. HOUFTON, PRESIDENT, IN THE CHAIR.

DISCUSSION OF MR. W. HUTTON HEPPLEWHITE'S PAPER ON "THE ACTION AND CONTROL OF DIFFERENTLY CONSTITUTED COAL-ROOFS."*

Mr. W. H. HEPPLEWHITE (H.M. Inspector of Mines, Tamworth), in replying to the discussion at the last meeting, said that Mr. Fraser's deductions with reference to pack-walls were altogether wrong. He was afraid that Mr. Fraser had failed to grasp the principle of arresting the roof depression. He had used his (Mr. Hepplewhite's) words, "a hard floor not subject to much upheaval," as if they referred to a soft floor. A hard floor required a foundation of penetrable material, so that the packs might become embedded as the roof depressed consistently with supporting the roof. The packs would take the depression, and, in all probability, without being bulged or pushed out. By remaining practically intact, the condition which Mr. Fraser said he had often seen, namely, packs crushed to less than half their original height, would certainly be obviated. Such a condition in pack-walls arose from collapse of the walls and continued roof depression, and this depression continued because the foundation had practically gone. Figs. 20 and 21 (Plate XXII.) referred to a soft floor, and the condition was notoriously altogether different from that of a hard floor. That floor proved the line of least resistance to the roof depression, and the packs easily penetrated it and caused the floor to lift from pack to pack. A soft foundation, such as he had described, would allow the packs to penetrate or to crush it flat, and the pack-walls would gradually arrest the roof depression and remain, on principle, intact. He did not wish to

* *Trans. Inst. M. E.*, 1911, vol. xlii., page 356.

convey the idea that the soft foundation should extend into the gate more than about a foot or so. That distance, he thought, was quite sufficient, and infinitely better than having wide gate-roads, which in many cases would be a great source of danger owing to falls of roof, independently of the increased cost of wider ripping lips.

With reference to the remarks of Mr. H. Watson Smith, he (Mr. Hepplewhite) was afraid that the figures relating to accidents in pits with differently constituted roofs were not obtainable. If Mr. Smith would refer to his (Mr. Hepplewhite's) remarks under the heading of "Line of Cleavage," he thought that he would find that the subject had been fully described. With regard to the width of the shift-up, if the coals were holed the width of the shift-up would be regulated thereby, and the advance of the coal-face would depend on the length of time that the web of coal was filled out. As to the dropping of the wastes, he presumed that this was to obtain the roof-coal that had been propped up. As it was only 16 inches thick at Ansley Hall Colliery, he was afraid that not much of it could be recovered with safety, especially with so friable a roof. Where the roof-coal had a thickness of several feet, the safest practice was to cut up at the pack sides of the waste and to work inwards, setting long supports to the roof above. The withdrawal of the back timber should take place a day or so after the packs had been built. Workmen were apt to shirk and neglect the withdrawal of timbers in the wastes, and this was the cause of much friction between the workers and the officials. A very interesting case had been tried a few weeks previously in Leicestershire. Some men were ordered to take out certain back timber, and they had refused. They were told that if they did not get it out, the "horse" would be stopped. They still refused, the horse was stopped, and the men refused to go back. They then summoned the firm for their wages for the time during which they alleged that they were not permitted to work. The County Court judge dismissed the summons, and refused to state a case.

He (Mr. Hepplewhite) was very pleased at Mr. Smith's endorsement of his views with regard to more accidents occurring under good than under bad roofs. It must be borne in mind, however, that there were more persons employed in mines with

comparatively good roofs than in mines with bad roofs. From his own experience, workers were extremely careful when having to deal with a bad roof, and he did not remember a single fatality in the very worst roofs with which he was acquainted.

On page 83 of the *Second Report of the Royal Commission on Mines*, the following remarks occurred with respect to roofs:—

"It is commonly supposed that the worse the roof of a seam, in the common acceptance of the expression, viz., the shorter and more broken the stone, the more liable to fall, and the more difficult to support, the greater is the danger to life from the same; but such is by no means universally the case. Certainly the number of minor accidents occurring in a seam with such a roof will be greater than that with, say, a stronger roof, but frequently the list of fatal accidents will be proportionately greater in the seam with the better roof, and the reason for this is not far to seek. The fact of the roof being bad calls for greater care, closer and better supporting, and when falls occur they are not commonly of the same magnitude as in the case of a stronger roof."

With reference to Mr. Pickering's criticism as to the meaning of "bannocking" or "breasting," he would suggest the following derivation:—Breast, to meet in front; breasting, opposing—opposing the holing. "Bannocking" was probably a corruption of banking, and "banking on top" was working on the top of the seam, or working on the pit-bank. He maintained that the coal-face was always the chief danger-zone with regard to falls of ground, and this was borne out by the following statistics extracted from a Government report* (Tables I. and II.):—

TABLE I.—DEATHS CAUSED BY FALLS OF GROUND IN AND ABOUT THE MINES OF GREAT BRITAIN AND IRELAND DURING THE YEAR 1910.

PLACE OR CAUSE OF ACCIDENT.	INSPECTION DISTRICT.								Totals.
	1	2	3	4	5		6	7	8	
	Scotland.	Newcastle.	Durham.	York and North Midland.	Manchester and Ireland. N. and E. Lancashire.	Manchester and Ireland. Ireland.	Liverpool and North Wales.	South Wales.	Midland and Southern.	
At the working-face	60	43	38	79	22	—	26	93	47	408
On roads while repairing or enlarging	10	6	8	23	7	—	14	34	14	116
On roads while otherwise working or passing	17	2	6	23	9	—	8	28	7	100
In shafts	2	1	—	8	—	—	—	1	—	12
Totals	89	52	52	133	38	—	48	156	68	636

* *Mines and Quarries: General Report, with Statistics for 1910, part i., District Statistics*, 1911 [Cd. 5794], pages 23 and 28.

TABLE No. II.—SEPARATE NON-FATAL ACCIDENTS BY FALLS OF GROUND IN AND ABOUT THE MINES OF GREAT BRITAIN AND IRELAND DURING THE YEAR 1910.

PLACE OR CAUSE OF ACCIDENT.	ALL NON-FATAL ACCIDENTS DISABLING FOR MORE THAN 7 DAYS.									Total Non-Fatal Accidents reported to Inspectors.
	Inspection District.								Totals.	
	1	2	3	4	5		6	7	8	
	Scotland.	Newcastle.	Durham.	York and North Midland.	Manchester and Ireland.		Liverpool and North Wales.	South Wales.	Midland and Southern.	
					N. and E. Lancashire.	Ireland.				
At the working-face	4,686	4,728	5,077	10,942	2,080	9	3,161	10,043	3,927	44,653	1,583
On roads while repairing or enlarging ...	418	384	276	1,145	250	—	549	1,888	537	5,447	269
On roads while otherwise working or passing	467	458	565	1,442	248	1	706	1,338	364	5,589	321
In shafts	12	11	4	8	10	—	8	42	1	96	8
Totals	5,583	5,581	5,922	13,537	2,588	10	4,424	13,311	4,829	55,785	2,181

It would be observed that the number of fatal accidents at the working-face was 408 and on the roadways 116; whilst the number of non-fatal accidents at the working-face was 44,653 against 5,447 on the roadways while repairing.

He thought that he was quite right in his contention that there were no records of sudden dislocations occurring in the British coal-field area since the beginning of coal-mining. It was awful to imagine a sudden dislocation of the strata occurring in an extensive mine, cutting off the whole of a district, and completely isolating the workmen, who would probably all perish, if the fault was of any extent, before a new road could be made through it. He was pleased to see that Mr. Pickering was in agreement with him as to soft material being placed under pack-walls. He thought that it would be a great advantage in securing better gate-roads if workers could be induced to bestow more care when building gateside packs. The inside should progress proportionately with the packers. Loose dirt should, as far as possible, be used for filling in the openings. A mark should be put on the roof as a guide where the pack should finish, and—as important an essential as any—some care should

be exercised in selecting the stone. He was aware of a few mines where stone was sent from another seam, not so much for ordinary packs, but as a preventive of gob-fires.

With regard to the fineness of the end of the Spencer prop for penetrating the floor when the roof-depression came on, he presumed that this could be regulated according to the amount of normal roof-depression and the material of which the floor was composed. If it were comparatively soft clunch, then the point should be somewhat stumpy; and if, on the contrary, it were hard, it could be pointed to suit either soft, medium, or hard floors. Mr. Spencer was amongst one of the first colliery managers who had quickly grasped the utility of the tapered prop, and he had consistently used it since he first introduced them. Mr. Spencer had experienced the same objection in connexion with the rigid metallic props as he (Mr. Hepplewhite) did in his early years, when cast-iron props were used: that was, they penetrated and broke the roof. There was this in favour of all rigid props: the workers and officials knew full well that if the pack-walls were not finished and the back rows withdrawn at the proper time, the cast-iron would snap and the steel bend.

With regard to Mr. Beckett's remarks, he had travelled much himself in Germany and had visited a few of the collieries there, but he had never seen props scooped out, although he had seen a large number of tapered props. One kind of taper he had had in mind when he had first introduced tapered props, and that was to leave a few inches of the prop-end solid and to make the taper above it; but the making of the taper had to be done by hand, which was costly, and was not so satisfactory as the present form of taper.

He had not personally seen the flushing, or hydraulic process, of filling wastes, but he had seen the wholesale filling in of highly-inclined seams after the coal had been worked from level to level. In Upper Silesia there was a process of filling the waste with sand run along pipes from the surface. It was very obvious that such a process could only be applied to dip workings and not too far in-bye. The following extract from a Government report might not be out of place in this connexion*:—

* *Mines and Quarries: General Report, with Statistics for 1910, part ii., Labour*, 1911 [Cd. 5940], pages 86-87.

"THE FLUSHING OR HYDRAULIC PROCESS OF PACKING WASTES IN MINES.

"In their Report on falls of roof and side the Committee appointed by the Royal Commission on Mines describe the hydraulic packing of goaves or wastes in mines as practised in France, in describing a possible method of adaptation of a method of working the thick coal in South Staffordshire. They state, 'If the method could be applied to the thick coal, it would result in the more complete extraction of that seam and, *combined with hydraulic stowage, the total prevention of gob-fires.*'"

"Since the date of that Report a deputation from the Hamilton Town Council, consisting of Mr. Henry Keith (ex-Provost) and Mr. Moffatt, visited some of the districts on the Continent where this process is in operation, the object being to determine whether it would be applicable in the case of the mines in the neighbourhood of Hamilton with a view to protecting buildings, etc., on the surface. The conclusion arrived at by Mr. Keith in his Report is to the effect that the system must be regarded as having passed a long way beyond the experimental stage, 'and is operated under conditions as unfavourable as any obtaining in Hamilton, so far as the stability of the surface is affected.' He stated further, that 'in every case it may be taken for granted that necessity and not economy was the origin of the system wherever it is practised . . . . . The necessity for supporting the surface is the first consideration, but it is not the only consideration, for experience has proved that this method of supporting the roof of workings liable to fracture has been accompanied by a material saving of human lives.'"

"In respect to the argument that the inclination of the seam worked makes all the difference in the applicability of this method, the seams varying from 15 to 25 degrees, whereas in many districts in this country they are flat, Mr. Keith correctly meets the point when he says 'The difference between a flat section (district of a mine) and a section on the incline is, that the water goes to the dip of an incline and finds its level on the flat, and has to be led away. In the practical work of stowing there is no more difference than in filling a box on the tilt with sand, and filling it with sand on the flat.'"

"As the operation is fully described on pages 159-162 of the Expert Committee's Report to the Royal Commission, I do not propose entering into detail here."

"With regard to the effect of the introduction of this system of packing at Essen, the following extract from Mr. Keith's report is worthy of serious consideration by those concerned in working coal in the neighbourhood of towns in this country":—

"'Essen in 1850 was a town with less than 10,000 inhabitants; it has increased by extending its boundaries to 6,245 acres with upwards of 230,000 inhabitants. It lies in the centre of the coal and iron districts of Western Germany. An English Commissioner reporting on another subject incidentally mentions (Cd. 4032) 'the whole of the municipal area is undermined by various coal works, and the former lack of care in the making of the mines has caused subsidences in a number of places.' In this city are situated the enormous engineering works of the great Krupp firm, and underneath these works and throughout, underneath the existing city, the coal continues to be extracted from eight seams, varying in thickness from less than 20 inches to 5½ feet.'"

"'The effect of old workings has been already alluded to and it suggests surface instability, yet everywhere the surface is covered with high buildings,

churches with lofty spires, engineering works with great chimney stacks, and enormous lengths of horizontal caissons for conveyance of gas or steam, together with turning lathes and heavy machinery—yet no disturbance of the surface is appreciable, though under these the coal is being extracted at the rate of 1,700 to 1,800 wagons per day, and the space being filled in by the hydraulic system. Probably in no other district will the system be submitted to so severe a test. At Marxloh, where four seams are being wrought out under the town, the stratum between the surface and the coal contains a thick bed of running sand. Here, in addition to the necessity of avoiding injury to numerous tenements of shops and houses four storeys in height, it is necessary to avoid any lowering of the surface which would render the land liable to flooding from the Rhine. It is the latter necessity as much as the former that has compelled attention and cost for the support of the surface in the region of the Rhine.' "

" 'At Wanne the control of the pits visited had recently been assumed by Herr Meyer, the general manager of the Shamrock Pits. Although these had been in operation for a number of years, and seemed to be almost elaborately equipped, he was proceeding to instal the hydraulic packing system, to reduce the general cost of working the coal, which for surface damage alone was costing 4d. to 5d. per ton. His criticism of the system was that the first blush of enthusiasm for it was passed, " but it has now resolved itself into a system of necessity." ' "

He did not see the advantage, or even the possibility, of applying the hydraulic process in extensive longwall working. The very fact of the strata depressing immediately at and over the coal-face would render the process of rigidly sustaining the roof stratum futile, simply because the depression had started over an extensive area, and before the process could be applied the whole superincumbent stratum would be set in motion. Given a seam with some inclination, and working in small panels out-bye, the process might with advantage be applied.

With reference to Mr. Walker's question, he was afraid that the Eight Hours Act had not been sufficiently long in force to afford reliable statistics regarding accidents. The annual tonnage for 1910 was less by 10 tons per underground person as compared with 1909. It was fairly generally conceded that the output per person had decreased by an amount varying from 3 to 7 per cent.

The President had touched upon an important matter, namely, that of moving the coal-face as rapidly as possible, so as to allow the workers to be under newly-exposed roof. The President thought that there would then be a smaller percentage of accidents. He quite agreed with Mr. Houfton, but he was afraid that the conditions of mining as a whole prevented the face from being moved forward quickly. The Nottinghamshire coal-field with its longwall working possessed a

unique position in regard to the comparative ease with which the coal was worked and in the bending disposition of the roof. The line of working-face was generally in a straight line, which was favourable for producing induced weights over the coal, thus reducing labour to a minimum, and the cleavage under normal conditions could always be relied upon. Even rigid supports did not remain sufficiently long under the roof to receive more than a few inches of the roof-depression. Quite a different condition of affairs existed where holing had first to be performed and an explosive used to bring down the coal. The breaking up of the coal and comparatively slow progress of the buttock allowed the roof to depress considerably in some seams. The bars were bent, and props broken, even before the web of coal was filled out. It was with such roofs as these that the utmost care and skill of the workers was required to prevent detached pieces of roof from falling. The roof-supports should be of a yielding nature. Pack-walls should be built as soon as possible after the buttock, the back timbers then withdrawn, and the roof allowed to depress without let or hindrance.

In answer to Mr. Laverick's question, the number of coal-cutting machines in 1910 was 1,959 and the total output 15,878,801 tons, making the quantity for each machine 8,105 tons. Assuming that the annual output for each man was 300 tons, each machine was capable of doing the work of twenty-seven men. The 1,959 machines mentioned by him included, of course, all types. The risk of accident where coal was worked by machines in place of hand labour was reduced by 15 to 25 per cent., and that would probably account for the fact of comparatively so few accidents occurring with machines.

Mr. W. E. Garforth had stated that each of the machines in use at the Altofts Collieries was equal to from sixteen to twenty men.

Mr. Garforth, who was an acknowledged authority on the working of coal by machines on practical and scientific principles, had very kindly furnished him (Mr. Hepplewhite) with some statistics upon work done at the Altofts Collieries.

In the Diamond Seam for the 14 years ending December, 1911, 2,888,133 tons of coal were raised without a fatal accident. Of this quantity, 2,460,917 tons were got by machine for 4 non-fatal accidents, or an average of 615,229 tons per reported

accident; and 427,216 tons by hand for 2 non-fatal accidents, or an average of 213,608 tons per reported accident.

Since the introduction of coal-cutting machines in 1892, 3,300,339 tons had been got by machine for 2 fatal accidents and 9 non-fatal accidents, or an average of 300,031 tons per reported accident.

Mr. Garforth attributed the difference (in respect of accidents) in favour of machine work to the straight line of cut inducing a straight line of fracture in the roof, which with the consequent straight line of timbering caused a regular settlement of the roof stratum. Mr. Garforth entirely endorsed the opinion expressed in his (Mr. Hepplewhite's) paper of utilizing Nature's forces in reaping the coal by paying attention to the line of cleavage and thus obtaining the full effect of the superincumbent strata.

Mr. W. Hay (Shirebrook) said that the work done by a coal-cutting machine was equal to that of twenty to twenty-two men. He did not think that they would get much above these figures. At a colliery with which he was connected they had not had a serious accident at the coal-face since they introduced systematic timbering about 18 years ago.

Mr. W. E. Walker (Nottingham) remarked that from memory he should say that the machines at Clifton would each do the holing of about twenty-eight men.

The President (Mr. J. P. Houfton) suggested that a paper giving a comparison between the working of machines and men would be of great value, and would enable them to lengthen the discussion on this particular point.

Mr. H. R. Hewitt (H.M. Inspector of Mines, Sheffield) said that he would like to emphasize Mr. Hepplewhite's remark, that he desired to see the same precautions used with regard to timbering good and bad roofs alike. His own observation convinced him that there were more accidents under good roofs than under bad ones. He thought that in every stall bars should be put up instead of only "where required." It often happened that there was an accident just beyond the point where the bars were discontinued, because it was thought that they were not needed.

Mr. G. ALFRED LEWIS (Derby) remarked that it was stated that more accidents took place on the roads than at the coal-face. Was that intended to mean proportionately to the number of workmen respectively employed? He thought that the moral of Mr. Hepplewhite's paper was, briefly, that if they could induce a workman to understand that the most dangerous part of the face was in front of the holed coal, they would be making some advance in the way of safety.

Mr. HEPPLEWHITE replied that he had calculated from the statistics that the ratio between the number of accidents and men employed at the coal-face was as 9 to 8—that was to say, about 80 per cent. of the men were employed at the coal-face and 90 per cent. of the accidents occurred there.

The PRESIDENT observed that a comparison between steel and tapered props would no doubt be interesting to some of them. He happened to have one colliery where they were using nothing but tapered timber props, and another colliery where steel props were exclusively in use. At the former colliery the cost of timber was from 3d. to 3½d. per ton of coal produced, and at the colliery where steel props were in use, the cost of the props—after allowing 25 per cent. for depreciation—came to a very minute fraction over one penny per ton. He must say that so far as the pit where the tapered props were used was concerned, he could not remember a single fatal accident having occurred. Over 2¼ million tons of coal had been brought out without a life being lost at the coal-face, and that, he thought, might perhaps be attributed largely to the fact that tapered props were used. They were especially suitable in this particular colliery, and he was glad to be able to use them, especially as there was no royalty to pay on them.

Mr. F. N. SIDDALL (Netherseal) said that Mr. Hepplewhite had evidently referred to the colliery with which he (the speaker) was connected, when he mentioned a case in which stone was brought from another seam for the purpose of building walls to prevent gob-fires. At Netherseal they were working a seam which was about 20 feet thick, and they had a district which lay 2½ miles from the pit-shaft, and had an inclination of 1 in 1¼. The waste had been built off within 12 feet of the face

entirely through the length of that particular district, a distance of about 300 yards. The stone which they had used was brought, as Mr. Hepplewhite had stated, from another seam, a part of which was also a corresponding distance from the shaft, so that altogether the material had to be conveyed something like 5 miles and over roads of heavy gradients. The real object was to save the district from gob-fires, and probably the work would not have been done if the place had not been subject to such fires. It had been found that the most economical way of working the coal was by the "longwall retreating" system. They must either bring in material from another mine, or use the coal itself for packing purposes, and that, of course, would be a very expensive proceeding. There was another point which he might mention. It was formerly the practice to use ordinary timber varying from 7 to 8 feet in length and from 8 inches to a foot in thickness, but now they used tapered props of the same sizes, and the cost had been reduced to a quarter of the original cost of timbering in the last 10 years.

The discussion on the paper was closed.

DISCUSSION OF MR. GEORGE H. WINSTANLEY'S PAPER ON "THE SAFETY-LAMP AS AN INSTRUMENT FOR THE DETECTION AND ESTIMATION OF FIRE-DAMP IN MINES."*

Mr. W. H. Hepplewhite (Inspector of Mines, Tamworth), referring to the necessity of the increased knowledge on the part of deputies required by the new Mines Act, said that in the Leicestershire district they had secured a large room where they had put up an apparatus for testing for small percentages of gas. They had a good attendance, and the deputies seemed to be taking very great interest in the question. A similar enterprise had just been started in South Derbyshire, where there were about 200 deputies, and they were asking the County Council to give them some assistance. It was essential that deputies should be able to read a gas-cap, to measure the ventilation, and to read a plan.

* *Trans. Inst. M. E.*, 1910, vol. xl., page 338.

He could not speak too highly of Mr. Winstanley's paper, which had appeared at a very opportune time. It must be understood that all the tests were made in a laboratory, and therefore varied considerably from those made in actual practice in the mine. The purity of the gas varied in different seams, and caps of varying colours and action on the flame were produced, whereas in the testing-chamber the caps were constant.

Mr. W. HAY (Shirebrook Colliery) pointed out that in that building (the University College) they had a splendid arrangement for the very purpose of testing for small percentages of gas, and the authorities would be delighted if members would go and look at it.

The PRESIDENT (Mr. J. P. Houfton) said that, with regard to Derbyshire and the parts of Yorkshire served by Sheffield University, classes were being held for mining lecturers, who were being examined and passed as teachers of deputies in the districts where the mining classes were usually held. For instance, at Bolsover, Cresswell, Eckington, and a number of other places where local mining classes were being carried on, the instructors were all being prepared to become teachers of the deputies in those districts. That would obviate the necessity of some of the deputies having to travel long distances in order to obtain the requisite instruction at centres like Sheffield, Nottingham, and Derby. He could assure Mr. Hepplewhite that in that district they were fully alive to the obligations which were imposed, not only upon colliery managers, but on deputies also by the new Mines Act. They might be working when the Act came into operation, but on the other hand there was a possibility that the pits might still be standing idle owing to the coal-strike.

Mr. F. N. SIDDALL (Netherseal Colliery) drew attention to a letter from Mr. T. A. Southern in the *Colliery Guardian*,* in which he published the correspondence that he had had with the Home Office on the subject of the examination and granting of certificates to deputies under the new Mines Act. The Home Office reply to Mr. Southern took the form of a circular letter

* 1912, vol. ciii., page 433.

specifying the requirements which were essential. These requirements included (1) testing for 2 per cent. and upwards of gas; (2) the use of the anemometer and the employment of dust or smoke for measuring air-currents; and (3) the hearing to be sufficiently acute to enable a man to hear the cracking of the roof.

Mr. P. J. Fenwick (Nottingham) said that one of the professors at Nottingham University College had informed him that the circular from the Home Office seemed to suggest a particularly stringent examination for deputies. A deputy was required to recognize not only 2 per cent. of gas, but various percentages, not merely with one safety-lamp, but any safety-lamp ordinarily employed in a mine, and with any of the oils—colza, or a mixture, or paraffin. There were a great many deputies who, unless they attended such classes as had been mentioned, would not be able to pass the test.

Mr. H. Watson Smith (Ansley Hall) thought that the chief point in Mr. Winstanley's able paper was the difference of the height of the "cap" with the different sizes of flame, and this was clearly and effectively shown by the photographs. In speaking about the size of the flame with relation to the height of the cap, Mr. Winstanley had confined himself to the size of the flame in height only, whereas he (Mr. Smith) had found that the width of the flame was also a determining factor in the height of the cap. This was the chief advantage of using a spirit flame, inasmuch as when a spirit-flame with a flat wick-tube was reduced so that no white flame was visible, it was found that the blue flame always extended practically over the whole width of the tube, giving in gas a larger and higher cap. This, of course, was most noticeable with percentages of 4 and under, and was therefore of the greatest importance; on the other hand, an oil-flame when reduced left the ends of the wick, and a flame of a smaller width and a cap of less size was obtained, provided that both wicks were trimmed perfectly level.

He (Mr. Smith) must confess that up to the time when he availed himself of the opportunity of carrying out some laboratory gas-testing experiments at the Warwickshire County Mining School, Nuneaton, with different luminants, he had always understood that the reason of higher caps produced by the spirit

flame was because of the higher temperature at which the flame burnt; but from experiments he had found that with exactly the same breadth and height of flames—oil and spirit—the caps were equal so far as ocular estimations could determine. Also that between 2 and 4 per cent., the height of the cap was proportional to the breadth of the flame.

Another factor in the size of the cap was the cleanliness and trimming of the wick. As was well known, the wick of an oil-lamp became clogged, and a "snuff" formed on the top of the wick, due to the products of combustion. When this cake was taken off with a pricker, it did not always leave the top of the wick level, and this affected the breadth of the non-luminous oil-flame and hence the size of the gas-cap. Here, again, was another advantage of the spirit-flame, in that the wick was always practically clean. The pricker in the oil-lamp was always a nuisance in the matter of regulating the flame, and one might often lose his light in the operation, and this had a tendency to prevent deputies from using as low a flame as was necessary for the detection of a small quantity of gas. The regulation of the flame by the use of a screw tended to overcome this difficulty.

He quite agreed with Mr. Winstanley that a safety-lamp was a most useful appliance, and would be the most generally used by firemen for showing indications of fire-damp, and allowing of the amount present being estimated fairly accurately to at least ½ per cent.; but, in order to estimate that quantity, such person must have the same lamp as that which he had used for laboratory tests, and which gave him his ideas of the sizes of cap with the different percentages—at least until he had become expert with all types of lamp in all kinds of gas-mixtures.

For the safety-lamp to be a reliable scientific instrument for gas-testing generally, it was very desirable that there should be a standardized gas-testing safety-lamp, just as there were standardized instruments, and that the lamp should be generally accepted and used by all firemen and others engaged in gas-testing. If this lamp were of a standard make, with a wick-tube and wick (standardized), and burning a standard illuminant—spirit for preference—it would be a great help to uniformity in estimating the gas present. It would be necessary, however, with a high volatile fuel to distinguish carefully between the fuel-cap and the

gas-cap when estimating percentages less than 2. The only thing left to the operator would be the adjustment of the height of the flame. He (Mr. Smith) realized the great importance of this, but in using a lamp with the standard conditions stated, the lowering of the flame, until all visible white light had just left it, should ensure that the height of the flame would be practically the same in all cases.

Another difficulty, in his opinion, in the estimation of percentages of gas in a pit was that the conditions were somewhat rough and ready; whereas, when a lamp was put into a testing-box, it was known that there was an unvarying fixed percentage of gas present. In the pit, on the other hand, there were varying percentages in and about the same place, due to many reasons. In all cases a reasonable time should be allowed, in order that the air might re-adjust itself to the conditions existing before the lamp was inserted in the mixture and the current through the lamp properly established.

Mr. ALLEN H. BONNER read the following paper on "The Causes of Boiler Deterioration and their Remedy":—

THE CAUSES OF BOILER DETERIORATION AND THEIR REMEDY.

By ALLEN H. BONNER.

Oil, corrosion, and scale are responsible for nearly all boiler repairs.

Corrosion.—The greatest cause of corrosion is, no doubt, due to the presence of animal and vegetable oils in the feed-water, when it is obtained from the hot-well of condensing engines, or when heated by exhaust-steam.

Oils of animal or vegetable origin are composed of glycerine chemically united with acids. When such oils are subjected to heat, they decompose into free acid and free glycerine. This decomposition takes place at a temperature of about 220° Fahr., which is the temperature of steam having a pressure a little above that of the atmosphere. It is thus seen that oils of animal or vegetable origin are not safe even in low-pressure boilers, with the temperature of the steam at an absolute pressure of 17 pounds per square inch. The glycerine is harmless, but with the liberated acid the case is wholly different, as the acid attacks the boiler-plates until it has carried away an amount of metal equivalent to the amount of glycerine that it has given up.

The chemical action between the boiler-plates and the acid results in the formation of a compound which either falls to the quieter parts of the boiler or sticks to the sides of the shell, and is familiar as a sticky black grease that must be removed from the boiler by mechanical means.

The best and most obvious remedy in such a case is to use oils that do not corrode. Mineral oils are composed of two elements, namely, hydrogen and carbon, and it is impossible to form an acid by any combination of these two; consequently, mineral oils, when subjected to the heat of steam, do not injure the boiler by attacking it chemically. Mineral oils, however, often cause injury to the boiler by settling on the plates, thus

preventing the water from carrying off the heat as quickly as the plates take it up from the fire, to such an extent that by simply rubbing a thin layer of mineral oil over a clean boiler-plate its temperature will rise 650° Fahr., even in the case of a moderately worked boiler.

The chemical affinity between glycerine and the acids of vegetable or animal oils is very weak; consequently they readily decompose on heating; but the attraction between these acids and lime (CaO), sodium carbonate or carbonate of soda (Na_2CO_3), and caustic potash (KHO) is exceedingly strong.

If it is absolutely necessary to use oils that contain acids, then sodium carbonate or caustic soda should be added to the feed-water. The acids from the oils combine at once with the soda, and are thus unable to attack the boiler-metal.

It is better to neutralize the acids with caustic soda instead of sodium carbonate, because there is less chance of carbon dioxide (CO_2) being set free. This substance does as much harm as, or more than, the fatty acids from the oil.

Any boiler-compound that contains free acid should never be used as a scale-solvent, for, while the acid will undoubtedly attack the scale, it will at the same time attack the plates at every point where the scale is loose or broken off.

Sodium chloride or common salt (NaCl) does not corrode the boiler in any way, and is not deposited until it forms two-fifths by weight of the water.

Calcium sulphate or sulphate of lime ($CaSO_4$) is not at all corrosive, although it forms by far the largest part of the scale found in the boilers.

Magnesium chloride ($MgCl_2$) is one of the most corrosive compounds found in feed-waters. It is composed of magnesium and chlorine, and when heated this union is broken up and hydrochloric acid (HCl) is set free. This acid attacks the boiler-plates, the result being a decided shortening of the life of the boiler. Corrosion resulting from the presence of magnesium chloride may be prevented by treating the water with either sodium carbonate or caustic soda.

Carbonates in solution in hard water are bicarbonates, or compounds of carbonates and carbon dioxide, so that carbonates are a source of free carbon dioxide which hastens corrosion. Furthermore, if sodium carbonate is used, lime-water—that is,

a solution of calcium hydroxide, $CA(OH)_2$, in water—must be added in order to take up the carbon dioxide. It should be observed that lime and lime-water are wholly different substances.

Calcium chloride ($CaCl_2$) acts similarly to magnesium chloride, and the description and preventives given for magnesium chloride will be found applicable to calcium chloride.

A coating of scale is an efficient protection against the corrosive action of the calcium chloride and magnesium chloride when it covers every part of the boiler. In this case the hydrochloric acid attacks the scale instead of the plates; but a coating of scale is seldom sufficiently continuous to protect all parts of the boiler, as scale is liable to crack off, thereby exposing the plates, which are at once attacked and corroded until covered by new scale.

Grooving.—Another form of local corrosion is grooving, which makes its appearance at the edges of the plates where they come together to form a riveted joint. Grooving is also found on flat boiler-heads next to the circumferential seam that joins the heads to the cylindrical shell, and around the points where the through-stays are secured to the heads.

The cause of grooving is as follows:—The boiler material first corrodes to a uniform depth at all points, and then the alternate expansion and contraction cause the projecting layer of corroded iron and boiler-scale to crack off at the line of greatest flexure, which is situated close to the riveted joints and around the stays, because the stays through the ends, and the double thickness of metal at the joints, cause a greater stiffness of the shell at these points. This results in a concentration of the bending along a line adjacent to the rigid portion. The parts thus uncovered are again attacked, and the above-described series of operations are repeated.

The prevention of grooving, so far as it results from rigid parts, is a designer's problem; and all that the operating engineer can do is to maintain the feed-water in as uncorrosive a condition as possible.

Pitting.—The presence of air in feed-water is known to have a serious and very injurious effect on boiler-plates. Feed-water exposed to the atmosphere absorbs the oxygen and nitrogen of

which air is composed. The nitrogen is perfectly harmless, but the oxygen in the presence of carbon dioxide quickly attacks the boiler-plates. Oxygen alone will not attack iron, but when carbon dioxide is present, the iron and carbon dioxide unite, forming ferrous carbonate ($FeCO_3$), and this unites with the oxygen, forming ferric hydrate, or red rust, and sets the carbon dioxide free. Red rust, having an excess of oxygen, is itself corrosive when in contact with iron, and always parts with some of its oxygen to the iron, forming ferrous hydrate or black rust, while the liberated carbon dioxide attacks the boiler. The same cycle is repeated, and continues so long as free oxygen is supplied.

Pitting is a very peculiar form of corrosion, which seems at first to be very erratic in its action instead of following well-defined laws. Small holes, varying from a sixteenth to as much as half an inch in diameter, will appear in various parts of the boiler, while the plate only a few inches away will not be corroded in the slightest degree. The parts most generally affected are the furnaces along the line of the grates, the interior of the shell at the water-line, the under side of the tubes, and the stays that are submerged when the boiler is in operation. At the water-line the pitting extends around the shell in a broad band, and is generally well marked in the middle of this band. The width of the band depends upon the fluctuation in the water allowed by the stoker. The explanation of this phenomenon is that pitting takes place at the water-line; but, as the water rises and falls, the pitting extends over a greater or a less surface, according to the regularity of the feed and the demand for steam.

Pitting may be attributed either to the presence of air in the feed-water or to galvanic action. It is probable that air in the feed-water is the greatest cause of pitting. When the feed-water is led to the lowest part of any internally-fired boiler, it does not immediately become heated to the boiling temperature; it is only when until by evaporation from the surface that it rises to the height of the fire-bars, and becomes sufficiently heated to give up its air. The air collects in bubbles on the sides of the furnace, and it is only when the bubbles have grown to a considerable size that they break away from the metal and rise to the top of the water. It is during the time of its contact with the plate that the damage is done. The carbon dioxide and the oxygen in the bubbles attack the iron, and cause the formation of small inden-

tations or irregularities on the surface of the metal. These irregularities cause subsequent bubbles to find a firmer lodgment, and the original depression is made continuously deeper, thus weakening the plate.

The scale of rust that results from the action of the oxygen in the air-bubbles is continually broken and caused to fall off by the alternate expansion and contraction of the furnace-metal. This action assists the corrosive effects of the air-bubbles by always presenting a clean fresh surface of metal to the air. The under sides of the tubes and submerged stays are sometimes found pitted, because the air-bubbles rising through the water find very secure lodgment if they happen to strike at the middle point of the under surfaces of the tubes or stays.

The pitting at the water-line can be explained by considering the action of an air-bubble when it has risen to the top of the water. Owing to capillary attraction, there is a film of water that encases the bubble and causes it to float on the surface of the water until it comes into contact with the boiler-shell. From this point, its action is the same as with the air-bubbles on the furnace sides.

A preventive of pitting is to coat the interior of the boiler with a thin coat of scale, by admitting feed-water containing sulphate of lime, or some other scale-forming chemical. The same object is achieved by fitting internal feed-pipes of iron. These pipes should be of sufficient length to allow the feed-water to attain a temperature nearly equal to the temperature of the water in the boiler before it emerges from the pipes. In this way the feed-water is caused to give up all its air while it is still in the pipes, and as a result the corroding effects of the air act on the pipes and not on the furnace tubes or the shell. This action in time destroys the internal piping, but it is much cheaper and easier to replace from 15 to 20 feet of ordinary iron piping than a corrugated furnace or boiler-plate.

A rapid circulation prevents the lodgment of air-bubbles on the plates, and it is always found that boilers with retarded or defective circulation suffer to a much greater extent than those whose design permits of a rapid flow of water from one part of the boiler to another.

Galvanic Action.—A current is established whenever a brass valve or piece of copper is brought into metallic contact with

the steel of the boiler, and this action is greatly strengthened if the water in the boiler contains the least acid. The steam-pipe and brass connexions, etc., represent the wire of a battery, and form a closed circuit for the transmission of the electric current. As is the case in the battery, the result of this action is a wasting away of the boiler-steel and a general pitting of the interior of the shell.

When a zinc plate is suspended in the boiler in good metallic contact with the boiler-plates, this action between the brass parts and the steel of the boiler ceases, while a galvanic action is established between the boiler-metal and the zinc. The result is the corrosion of the zinc and the protection of the boiler-plates.

It is the custom in the United States Navy to suspend slabs of zinc from the through-stays in the steam-space by means of iron straps: care being taken to make good metallic contact between each piece of zinc and its suspending strap, and between each strap and the shell. Each joint is then made watertight by means of cement. A zinc basket or trough is provided, and is secured to the iron strap in order to prevent the disintegrated zinc from falling to the bottom of the boiler.

Another method of prevention is to paint the inner surface of the boiler with zinc white (ZnO), which has a beneficial effect, and is easily and cheaply applied. It has long been known that, when boiler-water is used over and over again, the zinc plates are not corroded so rapidly as when the water is constantly changed.

Boiler-scale.—The reports of the principal steam-boiler inspection and insurance companies show (1) that a large percentage of boilers are defective in ways that can be traced to impure feed-water; (2) that scale reduces the transmission of heat through the boiler heating-surfaces, so that, as compared with clean boilers, from 5 to 10 per cent. more coal is required to produce the same amount of steam; (3) that the presence of scale so cuts down boiler-capacity that in many cases additional boilers must be installed to provide steam that could be furnished by the existing boilers if kept clean; (4) that scale in boilers runs up a large yearly bill for cleaning; (5) that the presence of scale causes strains, leaks, cracks, bulges, and burns in the plates and tubes, and is a source of expense as represented by repairs and replacements; (6) that there is considerable expense

in firing up boilers which have been put out of service for repairs and cleaning, in addition to the interest charges on idle boilers; and (7) finally that impurities in the water are responsible for a large annual depreciation-charge, as represented by the shortened life of the boilers, due to corrosion, pitting, cleaning, expansion, and contraction-strains. It will therefore be seen that the presence of scale becomes a question of the utmost importance, more especially where quick-steaming boilers working at high pressure are employed.

It is absolutely necessary to keep the plates clean on both the fire side and the water side; especially is this so in the latter case, otherwise, if scale be allowed to accumulate, the plates will probably get red-hot, soften, and burst under pressure.

A British Admiralty report states that 0·10 of oil, 1·0 of scale, and 10·0 of steel offers equal resistance to the transmission of heat. It was also found that in a small experimental boiler the difference in the temperature between the plates and the water was 85° Fahr.; with a greasy deposit a sixteenth of an inch thick on the plates this difference rose to 151° Fahr. When this layer of grease was spread up the sides of the boiler, the temperature of the plate rose to 617° Fahr., showing a difference of temperature between the boiler-plate and the water of no less than 532° Fahr. Tests made in actual working proved that there was a great wastage of heat due to a thin coating of grease deposited on the tubes during the ship's trials, and caused a loss in efficiency (compared with clean tubes) of 11 per cent.

Temporarily Hard Water.—The chief bodies to be considered in this water are calcium carbonate and magnesium carbonate, better known as carbonate of lime and carbonate of magnesia respectively.

Although calcium carbonate is insoluble in ordinary water, yet it may be dissolved in water charged with carbon dioxide, and by this means it is converted into the soluble bicarbonate, as shown in the following equation:—

$$CaCO_3 + CO_2 + H_2O = Ca(HCO_3)_2.$$

The case is exactly the same with magnesium carbonate, the reaction being:—

$$MgCO_3 + CO_2 + H_2O = Mg(HCO_3)_2.$$

In both cases the soluble calcium and magnesium bicarbonates are formed.

If the above water be heated, the carbon dioxide will be evolved, owing to the decomposition of the bicarbonates, thus precipitating the insoluble calcium carbonate and magnesium carbonate.

Another method of softening temporary hard water is by the addition of lime, which precipitates the insoluble calcium carbonate and magnesium carbonate as shown in the following equations:—

$$Ca(HCO_3)_2 + CaO = 2CaCO_3 + H_2O.$$
$$Mg(HCO_3)_2 + CaO = MgCO_3 + CaCO_3 + H_2O.$$

The water can also be softened by adding sodium carbonate (Na_2CO_3) as under:—

$$Ca(HCO_3)_2 + Na_2CO_3 = CaCO_3 + 2NaHCO_3.$$
$$Mg(HCO_3)_2 + Na_2CO_3 = MgCO_3 + 2NaHCO_3.$$

It will be seen from the above equations that, no matter which reagent is used, the insoluble calcium and magnesium carbonates are precipitated in both cases, leaving the harmless sodium bicarbonate in solution in the latter case.

Permanently Hard Water.—This water cannot be softened by boiling, its hardness being due chiefly to the calcium and magnesium sulphates. Calcium sulphate is present in nearly all waters, and is not removed by boiling or liming. Its presence gives rise to a very troublesome form of scale in the boiler. It is soluble in ordinary water, but its solubility decreases as the temperature of the boiling water increases, until at a temperature of 300° Fahr. it becomes completely insoluble. It will be interesting to note that this is the temperature of steam at a pressure of 70 pounds per square inch.

Permanently hard water can be softened by the addition of sodium carbonate, according to the following equations:—

$$CaSO_4 + Na_2CO_3 = CaCO_3 + Na_2SO_4.$$
$$MgSO_4 + Na_2CO_3 = MgCO_3 + Na_2SO_4.$$

It will be seen from the above equations that the insoluble calcium and magnesium carbonates are again precipitated, leaving the harmless sodium sulphate (Na_2SO_4) in solution.

As an example, the writer will consider for a moment a feed-water containing the following bodies in solution:—

Calcium bicarbonate	$Ca(HCO_3)_2$
,, sulphate	$CaSO_4$
,, chloride	$CaCl_2$
,, nitrate	$Ca(NO_3)_2$
Magnesium bicarbonate	$Mg(HCO_3)_2$
,, sulphate	$MgSO_4$
,, chloride	$MgCl_2$
Iron bicarbonate	$Fe(HCO_3)_2$
Silica (in suspension)	SiO_2
Carbon dioxide...	CO_2
Hydrogen sulphide	H_2S
Mineral acids and air	

If the boiler be fed directly with this water, the effect of each body in the boiler and its remedy will be as follows:—

$Ca(HCO_3)_2$	Soft scale, remedied by heat.
$CaSO_4$	Hard scale, remedied by heat and Na_2CO_3.
$CaCl_2$...	May cause corrosion, remedied by Na_2CO_3.
$Ca(NO_3)_2$	Corrosion, remedied by Na_2CO_3.
$Mg(HCO_3)_2$	Soft scale and foam, remedied by heat.
$MgSO_4$	Hard scale, remedied by heat and Na_2CO_3.
$MgCl_2$	Corrosion, remedied by Na_2CO_3.
$Fe(HCO_3)_2$	Sludge, remedied by contact with air and heat.
SiO_2	Sludge, remedied by filtering.
CO_2	Corrosion, remedied by heat.
H_2S	Corrosion, remedied by heat.
Mineral acids and air	Corrosion, remedied by Na_2CO_3.

By adding sodium carbonate to the above feed-water, the insoluble carbonates are precipitated, leaving the various bodies in solution. It is not always necessary to add sodium carbonate to the feed-water. For instance, if the feed-water contained $Ca(HCO_3)_2$, $Mg(HCO_3)_2$, $Fe(HCO_3)_2$, SiO_2, CO_2, H_2S, and air, it would then be temporarily hard water, and it would be unnecessary to add a reagent, as this water may be softened by heating prior to its entry into the boiler. By thus removing the carbon dioxide by the application of heat, the soluble but sludge-forming bicarbonates are converted into insoluble carbonates, which are precipitated. It is preferable, when using either temporarily or permanently hard water for boiler purposes, always to heat the water before adding any reagent, as by so doing, the amount of reagent required will be reduced. The feed-water could be heated by exhaust-steam, and in such a case the steam should pass through an oil-separator, that is, where the steam and water mix together. It would also be advisable

to add a little caustic soda or carbonate of soda (if vegetable oil is used) to take up any free acid which may be present in the water after heating as previously explained.

Summary.—Generally speaking, the reactions in all water-softening plants may be summarized as follows:—

(1) Carbonates dissolved in water containing carbon dioxide treated with lime yield double the quantity of insoluble carbonates, as under:—

$$CaCO_3 + H_2O + CO_2 = Ca(HCO_3)_2.$$
$$Ca(HCO_3)_2 + CaO = 2CaCO_3 + H_2O.$$

(2) A soluble lime-salt treated with sodium carbonate yields insoluble calcium carbonate and a soluble soda salt, as under:—

$$CaCl_2 + Na_2CO_3 = CaCO_3 + 2NaCl.$$

(3) A soluble magnesium-salt treated with caustic soda yields insoluble magnesium hydrate and a soluble sodium salt, as under:—

$$MgSO_4 + 2NaOH = Mg(OH)_2 + Na_2SO_4.$$

(4) Sometimes caustic soda, when added to the original water with the carbon dioxide, forms soluble carbonate of soda, freeing the insoluble carbonates, and the sodium carbonate so formed is used for reaction, as under:—

$$Ca(HCO_3)_2 + 2NaOH = CaCO_3 + Na_2CO_3 + 2H_2O.$$

It is very desirable that all feed-waters should be heated before entering the boiler—either by the flue-gases or by the exhaust-steam. Much fuel is wasted where the feed-water is not heated previous to use, as in no other way can the latent heat of exhaust-steam be directly recovered.

Mr. William Beckett (Ilkeston) said that in one part of the paper there seemed to be a kind of paradox, as it was stated that in the United States Navy zinc plates were hung by an iron strap in the boiler, and underneath these zinc plates was a zinc trough. He thought that galvanic action was quite as likely to attack the zinc trough as to attack the zinc plates suspended above it.

The President (Mr. J. P. Houfton) remarked that the question of boiler preservation was of very great importance to them at the present time, when the size of the boilers and the pressure of the steam used at their collieries showed a continual tendency to increase. If any information could be derived

from the paper which would teach them something they did not know before as to how to treat the feed-waters of their boilers and to prevent corrosion, the paper would not have been written in vain. So far, he had never seen an entirely satisfactory water-softening plant which was capable of highest possible efficiency under all circumstances and conditions at a colliery. The supply of water from hour to hour varied so considerably that it was almost impossible to get the exact chemical mixture in a softener to enable it to perform with the fullest efficiency its work upon the feed-water. It was well known to most of them that their feed-waters did vary materially, although they might come from exactly the same source. The impurities in the feed-waters varied, especially in water from shallow wells. In a rainy season the water was much softer than in a dry season. Although there was an enormous number of makers of softening plant, none of them yet had designed a perfect type of feed-water softener. He thought that their thanks were due to Mr. Bonner for the paper that he had written. It was well to know that they had young members willing and able to give the time, the observation, and the trouble necessary to provide such capable papers. He moved that the discussion be adjourned, so as to admit of a more complete study by the members of Mr. Bonner's paper. He would like, however, first to mention an experience that he had had at the first colliery of which he was manager. It was in the borough of Manchester, and there was no railway connexion, but merely a connexion with the arm of a canal. Next door to them on the arm of the canal was a large wire-galvanizing works, and barges filled with carboys of sulphuric acid were brought up to be unloaded there. It was no uncommon thing for the carboys to be broken, and the contents to get into the canal, from which they drew their feed-water for the colliery. He remembered that when he first went to that colliery the cost of repairs to the boilers—a range of about eight—was considerably over £1,000 a year. They managed afterwards to find another source of water-supply, and the cost of repairs then went down very materially.

Mr. J. A. Longden (Stanton-by-Dale) wrote asking how the writer tested the temperature of the plates up to 650° Fahr.; and had he any real authority for saying that mineral oils caused

injury to the plates? His suggestion to use caustic soda to counteract acids would result in the formation of soap, and would cause priming. Red rust fell off and exposed fresh iron to the corrosive action. At Stanton the most serious pitting was round the blow-off taps, and it was thought that this was started by a sort of sand-blast action produced whenever the boiler was blown off. As to air in the feed-water, the insurance companies insisted that the water should be delivered above the level of the tubes in Lancashire boilers, so that in case the feed failed, water could not syphon back out of the boiler. The latter part of the paper referred to heating the water before adding any re-agent, so as to reduce the quantity required. The amount of lime would be reduced, but not the amount of soda. The waste through not heating the feed-water referred to in the last portion of the paper might be overcome by using condensing engines.

Mr. A. H. Bonner (Heanor), in replying to Mr. Beckett's point, said that the zinc basket was not in the water, but in the steam-space, and it was insulated from the boiler, so that no current could pass through. The zinc plates were above the water and not in it.

In reply to Mr. Longden, he might state that this rise of temperature of 650° Fahr. had been arrived at by experiments carried out in a small cylindrical boiler. Mineral oils had not the same disastrous effect on boiler-plates as vegetable oils.

As Mr. Longden had remarked, it was very advisable to deliver the water above the boiler-tubes. The feed-pipe should be fixed below the working-level of the boiler water; if the internal feed-pipe were fixed, say, at the working-level, it would be liable to become half full of steam and half full of water; then if colder feed-water were admitted, water-hammer was very liable to occur. Feed-valves had been fractured from this cause, owing to the internal feed-pipe being fixed too low.

Of course, the waste-heat of exhaust-steam might be utilized by using condensing engines, but this was not recovering the waste-heat directly, as would be the case mentioned in the last clause of the paper.

The further discussion of the paper was adjourned.

THE MINING INSTITUTE OF SCOTLAND.

ANNUAL GENERAL MEETING,

HELD IN THE ROOMS OF THE INSTITUTE, 39, ELMBANK CRESCENT, GLASGOW, APRIL 13TH, 1912.

MR. ROBERT McLAREN, RETIRING-PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The SECRETARY submitted the annual report of the Council, as follows:—

ANNUAL REPORT OF THE COUNCIL, 1911-1912.

This is the thirty-fifth annual meeting of the Institute, and the Council have the pleasure of submitting their thirty-fourth annual report.

The number of members on the roll, at this date, is as follows:—

Honorary members	3
Life members	6
Life associate member	1
Members (subscription, £2 2s.)... ...	207
Members (subscription, £1 5s.)... ...	352
Associate members	34
Associates	19
Students	15
Non-federated members (subscription, £1 1s.)	12
Non-federated member (subscription, 10s.6d.)	1
Total	650

This compares with the number on the roll last year as follows:—

On the roll at April, 1911		654
Added during the year		30
Total		684
Died	6	
Retired	12	
Struck off through non-payment of subscription	16	34
At present on the roll		650

This shows a net decrease in membership of 4 for the year.

The students' societies affiliated with the Institute are the Coatbridge Technical School, with 28 members; and the Hamilton Technical School Mining Students' Society, with 16 members; in all, 44, being 15 less than last year.

The following papers, with discussions thereon, have been before the members and published in the *Transactions*:—

"Wire Ropes as applied to Mining." By Mr. Dugald Baird.

"Testing of Fire-damp and Black-damp by Means of a Safety-lamp." By Mr. Henry Briggs.

"The Walker Overwinding-prevention Gear for Colliery Winding-engines, as fitted at the Mary Pit of the Lochgelly Iron & Coal Company, Limited." By Mr. John Paul.

"An Outburst of Coal and Fire-damp at Valleyfield Colliery, Newmills, Fife." By Mr. Henry Rowan.

"Description of the Aërial Ropeway from the Shale-mines to the Oil-works at Oakbank, Mid-Calder." By Mr. J. Balfour Sneddon.

"Memoir of James Stedman Dixon."

At the annual meeting on April 12th, 1911, and at a special meeting a week later, the members of the Institute discussed the Mines Bill then in Committee in Parliament. The discussion was not printed in the *Transactions*, but a digest of it was prepared by the Council and sent to the members and to all the Members of Parliament.

The summer meeting took the form of a pleasure excursion, on August 5th, 1911, by turbine steamer to Inveraray. Its success has led the Council to submit for the consideration of the Institute that a pleasure excursion be arranged annually.

An opportunity was afforded of a visit to the works of Rosyth Docks. The party was limited to fifty; and those who were fortunate enough to be balloted in the fifty had a most enjoyable and instructive visit.

It is with deep regret that the Council have to report the death of Dr. James Stedman Dixon and Mr. Archibald Blyth, two of the most respected office-bearers of the Institute.

Dr. Dixon, who twice held the office of President of the Institute, took the deepest interest in its welfare. A memoir of him, with portrait, is published in the *Transactions*.

Mr. Blyth was one of the original ten who founded the Institute in 1878. He was a member of Council from the beginning, acted as Treasurer from 1886 to 1906, and was thereafter appointed a Vice-President. No member of the Institute was held in higher esteem than he.

The attendance at the general meetings in Glasgow since the removal of the headquarters thither has been gratifying.

The Treasurer's financial statement for the year shows a smaller balance in hand than for the former year. This is chiefly due to the payment which had to be made to get quit of the rooms in Hamilton, which were held on a lease expiring in 1916. The rent for the period was £225, and by payment of £100 an arrangement for release of the Institute's obligations was effected.

There have been eight meetings of Council during the year.

The SECRETARY read the annexed duly audited abstract of the Treasurer's accounts for the year.

The report and abstract of accounts were unanimously approved; and a vote of thanks was awarded to Messrs. John McLuckie and John Nivison for their services as Auditors.

The following gentlemen, who had been duly nominated, were elected:—

MEMBERS—

Mr. JOHN M. CAIRNCROSS, Balmoral Terrace, Cambuslang, Glasgow.
Mr. JAMES CARLYLE, Elmbank Street, Bellshill, Lanarkshire.
Mr. JOHN FINLAY, Station Road, Law, Carluke.
Mr. JOHN R. GORDON, 90, Great Western Road, Glasgow.
Mr. ALEXANDER NEILSON HINSHALWOOD, Parkfoot Cottage, Dennyloanhead, Bonnybridge, Stirlingshire.
Mr. ELIJAH LANGLEY, Dalkeith Colliery, Dalkeith.
Mr. JOHN ALLAN WILSON, Irrigation Bungalow, Tissa, Southern Province, Ceylon.

ASSOCIATE MEMBER—

Mr. DEBENDRA N. DAS, The University, Glasgow.

The following proposals were submitted by the Secretary, on behalf of the Council, and unanimously agreed to:—

(1) That there be a yearly pleasure excursion of the members and friends of the Institute in summer.

(2) That there be an annual dinner of the Institute in the latter part of each year, to be held in Glasgow and Edinburgh alternately.

(3) That, in order to ascertain what is the best place and time for the general meetings, a trial be made for one year in Glasgow and Edinburgh alternately, at a suitable hour on the afternoon of Saturday.

THE TREASURER IN ACCOUNT WITH THE MINING INSTITUTE OF SCOTLAND, FOR THE SESSION 1911-1912.

RECEIPTS.	£	s.	d.
To Balance from Session 1910-1911	450	10	6
„ Members' Subscriptions—			
„ Arrears—			
1 Member, Session 1910-1911	2	2	0
1 Member, „ „ balance ...	1	1	0
„ Subscriptions—			
202 Members, Session 1911-1912 @ 42s. 0d.	424	2	0
328 Members, „ „ „ 25s. 0d.	410	0	0
11 Members (non-fed.) „ „ „ 21s. 0d.	11	11	0
1 Member, „ „ „ 10s. 6d.	0	10	6
31 Associate members, „ „ „ 42s. 0d.	65	2	0
16 Associates, „ „ „ 25s. 0d.	20	0	0
12 Students, „ „ „ 25s. 0d.	15	0	0
44 Students affiliated „ „ „ 3s. 0d.	6	12	0
„ Subscriptions in advance—			
9 Members, Session, 1912-1913 „ 42s. 0d.	18	18	0
7 Members, „ „ „ 25s. 0d.	8	15	0
1 Associate member „ „ „ 42s. 0d.	2	2	0
1 Member, Session 1913-1914 (to a/c) „ 25s. 0d.	0	5	0
„ *Transactions* etc., sold	7	13	6
„ Interest	14	13	9
„ Rents	1	6	6
	£1,460	4	9

PAYMENTS.	£	s.	d.	£	s.	d.
By Printing and stationery				81	16	3
„ Books and bookbinding				16	5	0
„ Rents and insurance				163	7	0
„ Salaries				106	8	0
„ Lighting				3	8	2
„ Stamps, telegrams, carriages				14	9	2
„ Sundries				2	14	7
„ The Institution of Mining Engineers for Calls, etc. (including £97 3s. 8d for Guarantee Fund)				663	5	10
„ Expenses of Council				50	0	1
„ Cleaning				0	10	0
„ Cash in Post-office Savings Bank ...	7	19	2			
„ „ Invested in 2½-per cent. Consols ...	80	15	0			
„ „ Motherwell Burgh Loan	250	0	0			
„ „ in Commercial Bank—						
Current account	0	16	7			
Deposit receipt	18	0	0			
„ „ in Treasurer's hands	0	9	11			
				358	0	8
				£1,460	4	9

Hamilton, April 2nd, 1912.—Examined, compared with vouchers, and found correct.

JOHN NIVISON,
JOHN McLUCKIE, } AUDITORS.

ELECTION OF OFFICERS, 1912-1913.

Office-bearers for the Session 1912-1913 were elected (the Vice-Presidents and Councillors by ballot), as follows:—

PRESIDENT:

Mr. JAMES HAMILTON, 208, St. Vincent Street, Glasgow.

VICE-PRESIDENTS:

Mr. JOHN GEMMELL, 10, St. Andrew Square, Edinburgh.
Mr. DOUGLAS JACKSON, Coltness Iron Works, Newmains.
Mr. DAVID M. MOWAT, Summerlee, Coatbridge.
Mr. JAMES B. SNEDDON, Oakbank, Mid-Calder.
Mr. WALLACE THORNEYCROFT, East Plean House, Bannockburn.
Mr. WILLIAM WALKER, Tyne Lodge, Grange Loan, Edinburgh.

COUNCILLORS:

Mr. ALEXANDER ANDERSON, Flemington Electrical Works, Wishaw.
Mr. DUGALD BAIRD, Lugar Iron Works, Cumnock.
Mr. MARK BRAND, Glenshirva, Twechar, Kilsyth, Glasgow.
Mr. DANIEL BURNS, Royal Technical College, Glasgow.
Mr. WILLIAM CALDWELL, Pumpherston, Mid-Calder.
Mr. WILLIAM CLARK, Gerson Park, Broxburn, West Lothian.
Mr. JAMES A. CLARKE, Ayr Collieries, Annbank, Ayr.
Mr. GEORGE GIBB, 51, Camphill Avenue, Crosshill, Glasgow.
Prof. J. W. GREGORY, The University, Glasgow.
Mr. THOMAS J. JAMIESON, Carronhall Collieries, Carron.
Prof. CHARLES LATHAM, The University, Glasgow.
Mr. SAM MAVOR, 39, Burnbank Gardens, Glasgow.
Mr. PETER MILLIGAN, Arniston Colliery, Gorebridge, Mid-Lothian.
Mr. ROBERT A. MUIR, The Grange, Bothwell, Lanarkshire.
Mr. JOHN PAUL, Lochgelly Collieries, Lochgelly, Fife.
Mr. HENRY ROWAN, Foulford House, Cowdenbeath, Fife.
Mr. WILLIAM SMITH, Dalmellington Ironworks, Ayr.
Mr. WILLIAM H. TELFER, Cransley, Pollokshields, Glasgow.

The RETIRING-PRESIDENT (Mr. Robert McLaren) then introduced the new President (Mr. James Hamilton); and, on the motion of Mr. JAMES T. FORGIE, a hearty vote of thanks was awarded to Mr. McLaren for his services as President during the past 3 years.

The PRESIDENT (Mr. James Hamilton) delivered the following Address:—

PRESIDENTIAL ADDRESS.

By JAMES HAMILTON.

During the discussion of the Mines Bill of 1911, now the Mines Act, which will come into force on July 1st, 1912, certain Members of Parliament drew a very lurid picture of the mines of Scotland, and limned some unflattering portraits of Scottish mine-owners and managers. This was, no doubt, largely due to the terms of the *Report of the Royal Commission on Mines* of 1909, wherein Scotland is regarded as the most dangerous of the several mines-inspection districts—a kind of frightful example—although the statistics in the report itself do not bear this out in many respects.

This led me to inquire how our mines compare as to safety with those of other parts of the kingdom, as shown by the reports of H.M. Inspectors of Mines since 1850. The result of this enquiry has been to satisfy me that the mines of Scotland are not nearly so black as they have been painted. I therefore take this opportunity of laying before the members of the Mining Institute of Scotland in Tables I., II., and III. a few figures showing the progress that has been made here in the last 60 years, compared with that of England and Wales, bringing out the particulars in which we are behind, as well as those in which we lead. This is done, not with the object of casting any reflections upon other mining districts, but simply to bring out the true position and to see how we really stand in comparison with others.

Every mining district has its own inherent difficulties and dangers, which cannot be exactly appraised and allowed for in a comparison drawn from mere statistics of accidents; but by widening the areas and extending the period under review, the varying conditions tend to equalize themselves and disappear

as a disturbing factor in the comparison. The wider the area is, the more nearly do the conditions as a whole approach the average; and, provided that the smaller area be not abnormally favourable in its mining conditions, the wider area must have the advantage in any comparison of safety tested by the record of accidents.

It cannot be contended that mining conditions in Scotland are exceptionally favourable for safe working, relatively to the average of Great Britain, except it be in the one particular of explosive gas. In that respect even, the advantage is probably more apparent than real, because most of our mines where explosive gas is found are on the boundary line, where it is a question of legitimate debate whether the use of closed lights would or would not reduce accidents as a whole. It does not, therefore, seem unfair to compare Scotland as a whole with England and Wales as a whole, although there is a great disparity in outputs. If there is any unfairness, the smaller area is more likely to suffer.

The basis of comparisons of this kind has been much discussed—whether it should be the number of persons employed, or the quantity of mineral raised. In the earlier reports of the Inspectors of Mines in the fifties and sixties, the comparison of accidents was made on the tons raised per life lost. It may be that they had then no choice, as they gave no return of persons employed, and even the output was an estimate. Recently the ratio of lives lost to persons employed has been very generally adopted; why, it is difficult to guess; but the earlier Inspectors of Mines, either by choice or by compulsion, selected the better test.

If it were a question of which mine is the safest in which to spend one's days, the ratio of accidents to persons exposed to danger is no doubt the true test, provided that the data are available and all the factors are taken into account. But the data are not available; because, apart from any question as to the accuracy of the statistics of men employed, no account is taken of the time during which the men are exposed to the dangers of the mine; and, consequently, the time-factor is entirely ignored in a comparison on the basis of men employed with our statistics as at present compiled. To illustrate the unsatisfactoriness of this test, it is only necessary to compare the returns of persons

employed and the output in good and in bad periods of trade. Take, for example, the long strike of 1894 in Scotland. The Inspectors' reports of 1893 give 74,830 persons employed underground for an output of 28,871,000 tons, and, in 1894, 77,743 persons underground for an output of 24,613,000 tons—a drop of over 4,000,000 tons of output concurrently with an increase of 2,913 men. Again, 1895 gave nearly 8,000,000 tons more output than 1894 with 60 fewer men underground. Examples could be multiplied almost indefinitely to show the unreliability of the statistics of men employed, and the need of a record of the number of man-shifts before the number of persons employed can be used as a basis of comparison of the safety of mines.

Even if fair data of this kind were available, the question, after all, is: What is the cost of raising a ton of coal expressed, not in cash, but in life and limb?

If from any cause, be it enterprise of the coal-owners and managers, or natural advantage in physical conditions, the quantity of mineral raised per man employed is greater in one district than in another, that district is fairly entitled to the benefit of that advantage as reflected in the statistics of accidents. I have therefore based the tables I have prepared on the tonnage raised, of which accurate figures are available. These show the number of lives lost per million tons raised in Scotland on the one hand, and England and Wales on the other, on the average over periods of 5 years beginning with 1853. The reason for adopting that seemingly odd date is that the beginning of a quinquennial period coincides with the beginning of both the Mines Acts of 1872 and 1887. Before 1860, the statistics of accidents in the Inspectors' reports were not given in any uniform way, and before 1872 I have given the deaths from accidents under the headings "Explosions," "Falls," "In Shafts," "Miscellaneous Underground," and "On Surface."

From 1853 till 1872, the number of lives lost per million tons raised in every class of accident was much higher in England than in Scotland. After 1872, the difference is much less marked, and only in one quinquennial period, namely, that ending 1877—the year of the Blantyre explosion—does Scotland stand higher in the ratio of deaths underground from all causes apart from shafts.

Dealing with the period from 1873 onward, only in the 5 years ending 1877 does Scotland show worse in "Explosions." It is uniformly better also in "Falls," except for a very slight difference against Scotland in the 3 years ending 1910. Haulage accidents are always higher in England, and on the average nearly 60 per cent. higher.

Throughout the period from 1873 to 1910, Scotland has the poorer record in the matter of shaft accidents, the average of that period showing almost 50 per cent. worse. The fatalities from overwinding and from the breaking of ropes and chains are practically equal. The difference is in those here classed as "Miscellaneous Shaft Accidents." Whether England's better record in this class is due to better shafts, fewer mid-shaft landings, or some other cause, the records do not enable me to say.

In surface accidents Scotland has been almost continuously worse since 1872. The proportionate difference is small, the average over the 38 years to 1910 being as 61 to 53.

The death-rate from accidents in using explosives is higher in Scotland in the ratio of 18 to 9. The statistics of explosives used, and shots fired, for the 4 years ending 1910 partly explain this. The quantity of explosives used per ton of mineral raised in Scotland is to the quantity used in England as 20½ to 9 and the shots fired as 15·4 to 9. We are therefore not quite so bad as the bare figures indicate.

In miscellaneous underground accidents we stand always on the wrong side of the account, the average over 38 years being as 58 to 40.

Only in two quinquennial periods during the whole 58 years since 1852 has Scotland a worse record than England in the total underground accidents, including shafts. These are the 5 years ending 1877, when the figures were 7·34 to 6·68, and the five years ending 1902, with 3·78 to 3·74.

On the average over the 38 years ending 1910, the figures for all underground accidents are: Scotland, 4·33; England, 5·00; and for all accidents—surface and underground—4·94 against 5·53. The difference is not great, but it is sufficient to show the injustice of singling out Scotland as the black sheep of mining in the United Kingdom.

While Scotland compares favourably on the whole, it has not

the best record among the several mines-inspection districts—at least three of these are distinctly better. These are Newcastle, Durham, and the Midland districts, while Yorkshire is on the same level, being on the whole very slightly better on the average over the last 38 years. The other districts are all considerably worse on the average over the same period.

What I have been endeavouring to bring out by figures is much better shown in diagrammatic form. A clearer idea of the progress of recent years is obtained through the eye than through the ear. The diagram (Fig. 1, Plate VI.) of all underground accidents shows the remarkable and rapid improvement that took place from 1853 to 1872, a period covering the development of mines inspection to approximately its present scale. From 1872 till 1897 the improvement, if less rapid, has been almost continuous. Only one set back has been experienced in each country during that time, each being due to one or more serious explosions. From 1898 to 1902 was the best period in England, and 1903 to 1907 the best in Scotland. The last 3 years have, on the average, gone back almost to the position in 1888 to 1892. But the 3 years ending 1910 not being a complete period, it does not afford a fair comparison.

Surface accidents have varied very little since 1882, and show no improvement since that date.

Taking the several classes of underground accidents the diagram for explosions (Fig. 2, Plate VI.) naturally shows the most ragged profile. The years 1903 to 1907 gave the best record in both countries, and the last three years (1908-1910) show an increase in both. In falls the decrease has been steady, and remarkably consistent. There is no case of an upward step from 1853 to 1902, but there has been a small rise in both countries since then. Haulage accidents show a tendency to increase since the 5 years ending 1897; and the increase is more marked in Scotland than in England. No doubt the increase of this class of accident is due to the necessary increase of mechanical haulage, with larger collieries and increasing outputs and changes in economic conditions.

Shaft accidents have gone very steadily down, showing that increased dangers of deeper winnings and more rapid winding have been more than met by better fittings and appliances.

There are no satisfactory data on which to base a comparison

of the several districts from the returns of non-fatal accidents. The difficulty of fixing a standard of what constitutes an injury to be reported is, and will most likely always be, an insurmountable barrier to the institution of a satisfactory comparison on that basis. The returns since 1908, when an attempt at uniformity in reporting was first made, vary so much in the several districts that one hesitates to use them. Taking them for what they may be worth, I find that they are very favourable to the mines of Scotland. On the average, over the 3 years ending 1910, the number of persons injured per million tons raised works out for Scotland at 313, and for England at 539. The best districts in England are Newcastle and Durham, which are equal with 497 persons injured, or fully one-and-a-half times the number in Scotland.

A striking feature of the statistics of persons injured is that more persons are reported injured by explosions of gas in Scotland than in the whole of England and Wales. Relatively to the output the figure for Scotland is 1·96, and for England 0·34 per million tons. The compulsory reporting of injuries by explosions, without reference to the extent of the injury, gives this item an exaggerated importance relatively to other accidents.

The injuries in shaft accidents in the two countries are practically the same, being for Scotland 3·1 and for England 2·9; and from explosives, 1·74 to 0·9. Under all the other heads our record in persons injured is much better than in any other mines-inspection district, without exception.

Noting the marked difference in the various districts in the number of non-fatal accidents, already referred to, and searching for an explanation, it occurred to me to compare the several districts in relation to these accidents, and the ratio of safety-lamps in use to men employed in the several districts. Fig. 3 (Plate VI.) is constructed to show the districts in ascending order of the proportion of safety-lamps to men employed in 1909, as shown by the thick line; and the number of persons killed and injured per million tons during the 3 years ending 1910, as shown by the thin line. It may be purely a coincidence, but it is a fact that, generally, the ascending order in proportion of safety-lamps is also the ascending order in accidents. The one exception is South Wales, which is, or course, always high in accidents.

FIG. 1.—DIAGRAM SHO
AND IN ENG
GROUND AND
MINERAL RE
REGULATION

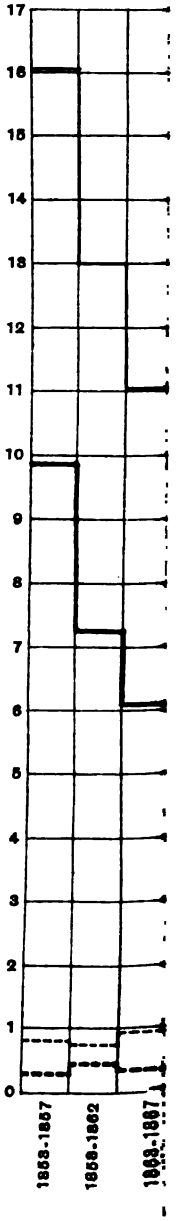
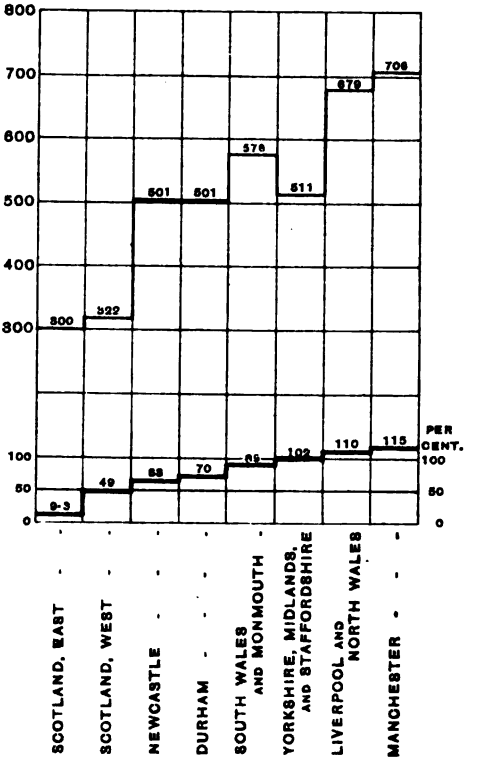


FIG. 3.—DIAGRAM SHOWING THE NUMBER OF PERSONS KILLED AND INJURED PER MILLION TONS OF MINERALS RAISED FROM MINES UNDER THE COAL-MINES REGULATION ACTS, IN THE SEVERAL MINES-INSPECTION DISTRICTS DURING THE 3 YEARS 1908–1910, AND THE RATIO OF SAFETY-LAMPS IN USE BY MEN EMPLOYED UNDERGROUND IN THESE DISTRICTS.



REFERENCES FOR FIG. 3.

PERSONS KILLED AND INJURED PER MILLION TONS RAISED - - - - - ———

PERCENTAGE OF SAFETY-LAMPS IN USE TO MEN EMPLOYED UNDERGROUND - - ———

Owing to the recent changes of Inspection districts it was necessary, in Fig. 3, to group the former Yorkshire, Midland, and Stafford districts in one, as they have been all mixed up in the new division. Similarly, Monmouthshire is grouped with South Wales. Scotland is, of course, also now one district, but it is possible to separate the two former districts. We all know the general mining conditions of the two districts, and the difference shown by the diagram appeals to all of us more than differences in other districts.

Referring again to the diagrams, I note that, except those of surface and haulage accidents, they have this feature in common—a continuous and rapid fall from 1853 till about 1890, followed for the last 15 to 20 years by a comparatively level line, with small fluctuations up and down. This suggests the question of whether, if we have not yet reached, we are not closely approaching the practical limit of safety. Theoretically, there is no limit till we reach that foreshadowed by Sir William Ramsay's speculations, when there will be no underground fatalities, because there will be no men underground. But there is a practical limit to the benefit that can be obtained by restrictive legislation, administrative and economic, which introduces new conditions that must be met by the application of new methods and appliances, each introducing its own dangers, so that it is beyond the wit of man to estimate beforehand what will be the ultimate effect, or to say this will, and that will not, on the balance, make for safety and not for danger. The Acts of 1872 and 1887 have both been followed by a decrease of fatalities, but, as the diagrams show, not in any increased rate of diminution. Let us hope that the Act of 1911 will at least check the tendency to increase which the last few years have shown to be characteristic of every district.

On the motion of Mr. GEORGE A. MITCHELL, a hearty vote of thanks was awarded to the President for his Address.

APPENDIX.—TABLE I.—SHOWING THE NUMBER OF LIVES LOST PER MILLION TONS OF MINERAL RAISED FROM MINES UNDER THE COAL-MINES REGULATION ACTS, IN SCOTLAND AND IN ENGLAND AND WALES RESPECTIVELY, IN PERIODS OF 5 YEARS FROM 1853 TO 1910.

	1853-1857.		1858-1862.		1863-1867.		1868-1872.		1873-1877.		1878-1882.		1883-1887.		1888-1892.		1893-1897.		1898-1902.		1903-1907.		1908-1910.		Averages since 1872.	
	Scotland.	England.	Scotland.	England.	Scotland.	England.	Scotland.	England.	Scotland.	England.	Scotland.	England.	Scotland.	England.	Scotland.	England.	Scotland.	England.	Scotland.	England.	Scotland.	England.	Scotland.	England.	Scotland.	England.
Underground—																										
Explosions ..	1·34	4·02	0·90	2·78	0·70	3·14	0·57	1·99	2·35	1·20	0·77	2·28	0·78	0·97	0·19	0·76	0·27	0·81	0·41	0·25	0·17	0·26	0·35	1·16	0·57	0·87
Falls	4·43	6·26	3·95	5·33	3·35	4·24	3·26	4·01	2·86	3·08	2·64	2·91	2·28	2·73	2·08	2·44	2·02	2 21	1·84	2·01	1·88	2·16	2·05	2·03	2·14	2·40
Explosives ..	—	—	—	—	—	—	—	—	0·09	0·16	0·11	0·08	0·16	0·10	0·25	0·10	0·18	0·08	0·22	0·08	0·21	0·09	0·18	0·08	0·18	0·09
Haulage	—	—	—	—	—	—	—	—	0·45	0·98	0·40	0·91	0·53	0·94	0·51	0·90	0·43	0·87	0·58	0·86	0·61	0·91	0·74	0·96	0·54	0·91
Miscellaneous ..	1·10	2·21	0·72	2·63	0·64	1·93	0·48	1·88	0·23	0·30	0·16	0·23	0·20	0·26	0·61	0·28	0·28	0·42	0·22	0·24	0·18	0·25	0·27	0·31	0·27	0·29
Total ..	6·87	12·49	5·57	10·74	4·69	9·31	4·31	7·88	5·98	5·72	4·08	6·41	3·95	5·00	3·64	4·48	3·18	4·39	3·27	3·44	3·05	3·67	3·59	4·52	3·70	4·56
Overwinding .	—	—	—	—	—	—	—	—	0·05	0·03	0·09	0·03	0·05	0·03	—	0·02	—	0·03	0·02	0·01	0·01	0·02	0·07	0·03	0·03	0·02
Breakage of ropes	—	—	—	—	—	—	—	—	0·05	0·06	0·02	0·06	0·03	0·04	0·01	0·01	0·04	0·01	0·04	0·02	—	0·01	—	0·02	0·02	0·02
Miscellaneous ..	—	—	—	—	—	—	—	—	1·26	0·87	0·75	0·57	0·60	0·39	0·59	0·41	0·50	0·34	0·45	0·27	0·39	0·25	0·39	0·21	0·58	0·40
Total in shafts	2·99	3·58	1·66	2·25	1·39	1·73	1·06	1·19	1·36	0·96	0·86	0·66	0·68	0·46	0·60	0·44	0·54	0·38	0·51	0·30	0·40	0·28	0·46	0·26	0·63	0·44
Total underground	9·86	16·07	7·23	12·99	6·08	11·04	5·37	9·07	7·34	6·68	4·94	7·07	4·63	5·46	4·24	4·92	3·72	4·77	3·78	3·74	3·45	3·95	4·05	4·78	4·33	5·00
Surface—																										
Machinery and boilers	—	—	—	—	—	—	—	—	0·23	0·17	0·12	0·10	0·07	0·07	0·08	0·09	0·13	0·08	0·10	0·08	0·15	0·10	0·11	0·08	0·12	0·10
Railways	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0·28	0·17	0·38	0·31	0·41	0·28	0·31	0·28	0·30	0·24	—	—
Miscellaneous ..	—	—	—	—	—	—	—	—	0·47	0·51	0·42	0·42	0·57	0·42	0·09	0·22	0·16	0·16	0·16	0·15	0·16	0·15	0·15	0·14	0·49	0·43
Total on surface	0·29	0·82	0·44	0·74	0·31	0·92	0·49	0·72	0·70	0·68	0·54	0·52	0·64	0·49	0·45	0·48	0·67	0·55	0·67	0·51	0·62	0·53	0·56	0·46	0·61	0·53
Grand total ..	10·15	16·89	7·67	13·73	6·42	11·96	5·86	9·79	8·04	7·36	5·43	7·59	5·27	5·95	4·69	5·40	4·39	5·32	4·45	4·25	4·07	4·48	4·61	5·24	4·94	5·53

APPENDIX. - TABLE II.—SHOWING THE NUMBER OF LIVES LOST PER MILLION TONS OF MINERAL RAISED FROM MINES UNDER THE COAL-MINES REGULATION ACTS, FOR EACH MINES-INSPECTION DISTRICT.

	1873-1877.		1878-1882.		1883-1887.		1888-1892.		1893-1897.		1898-1902.		1903-1907.		1908-1910.		Average over 38 years.	
	Underground.	Surface.	Underground.	Surface.	Underground.	Surface.	Underground.	Surface.	Underground.	Surface.	Underground.	Surface.	Underground.	Surface.	Underground.	Surface.	Underground.	Surface.
Scotland, East	8·53	0·68	4·62	0·59	4·86	0·66	4·26	0·47	3·61	0·73	3·63	0·71	3·33	0·66	4·04	0·57	4·40	0·62
Scotland, West	5·70	0·73	5·48	0·45	4·14	0·58	4·22	0·41	3·88	0·59	3·96	0·62	3·52	0·57	4·09	0·54	*4·21	0·57
Average for Scotland.. ..	7·34	0·70	4·94	0·54	4·63	0·64	4·24	0·45	3·72	0·67	3·78	0·67	3·45	0·62	4·05	0·56	4·33	0·61
Newcastle	4·59	0·70	3·56	0·54	3·83	0·41	3·85	0·51	3·38	0·39	2·89	0·73	2·77	0·51	4·57	0·46	3·55	0·52
Durham	3·43	0·63	5·37	0·39	3·09	0·32	2·55	0·26	2·82	0·37	2·85	0·42	3·13	0·52	4·37	0·47	3·40	0·42
York and Lincoln	7·54	0·92	4·76	0·55	4·88	0·49	3·76	0·45	5·09	0·68	2·86	0·71	3·60	0·63			4·29	0·63
Midland	5·18	0·24	4·44	0·47	3·50	0·45	2·80	0·36	2·28	0·49	2·62	0·27	2·48	0·35			3·20	0·37
North Stafford	9·27	0·48	8·67	0·32	4·77	0·22	6·86	0·57	6·24	0·88	4·29	0·55	4·38	0·31	3·72	0·51	*6·60	0·49
South Stafford	6·66	0·52	4·80	0·30	4·27	0·45	3·78	0·33	4·09	0·37	—	—	—	—			†4·78	0·42
Manchester	8·06	0·60	6·92	0·44	11·41	0·38	5·10	0·49	5·40	0·43	4·21	0·33	3·78	0·40	14·50	0·38	6·82	0·42
Liverpool and North Wales	10·05	1·18	11·18	1·05	5·47	0·75	6·21	0·59	4·73	0·66	4·57	0·49	4·06	0·48	6·14	0·53	6·28	0·69
South Western..	9·28	0·79	17·54	0·50	6·61	0·50	8·82	0·57	4·52	0·60	4·13	0·47	4·97	0·67	5·04	0·47	*7·14	0·57
South Wales	8·15	0·69	10·55	0·66	9·59	0·81	8·91	0·80	9·86	0·77	6·43	0·67	6·42	0·71	6·02	0·62	8·05	0·72
Av. for England and Wales..	6·68	0·68	7·07	0·52	5·46	0·49	4·92	0·48	4·77	0·55	3·74	0·51	3·95	0·53	4·78	0·46	5·00	0·53

* Average of 37 years. † Average of 28 years.

APPENDIX.—TABLE III.—SHOWING THE NUMBER OF PERSONS INJURED PER MILLION TONS OF MINERAL RAISED FROM MINES UNDER THE COAL-MINES REGULATION ACTS DURING THE 3 YEARS 1908 TO 1910.

Mines-inspection District.	Underground.	Surface.
Scotland	314	25
Newcastle	497	28
Durham	494	33
York and Lincoln	507	43
Midland		
Stafford		
Manchester	692	48
Liverpool and North Wales	672	54
South Western	571	42
South Wales		

DISCUSSION OF MR. JOHN PAUL'S PAPER ON "THE WALKER OVERWINDING-PREVENTION GEAR FOR COLLIERY WINDING-ENGINES," ETC.*

Mr. JAMES BLACK (Airdrie) said that in the introduction to his paper Mr. Paul had stated that in designing the overwinding-prevention gear the object was to provide a simple, reliable, and inexpensive device. The Walker overwinding-prevention gear was no doubt simple, and should be inexpensive, but, in his opinion, it was very far from being reliable. It gave very little security against the cage being drawn into the headgear or lowered into the pit-bottom at a high velocity, as the ascending cage could pass the predetermined cut-off point at any velocity, be it ever so high, provided that at the same instant the engine-man only momentarily closed the steam-throttle. Further, it offered no security against the cages running wild in the event of an accident occurring to the engineman during the time when a heavy load was being lowered into the pit-bottom.

These were shortcomings which were far too serious to be lightly passed over, and, in his opinion, showed clearly that the device was altogether incapable of fulfilling the functions of a well-designed overwinding-prevention gear. It would not have been necessary for him to have commented on the Walker over-winding-prevention gear apart from the Walker controlling gear —in conjunction with which it was at work at the Mary Pit,

* *Trans. Inst. M. E.*, 1911, vol. xlii., page 308.

Lochgelly—had it not been for the fact that Mr. Paul in his paper explicitly stated that either of these gears might be used independently.

The introduction of the Walker controlling gear to work in conjunction with the Walker overwinding-prevention gear was, in his opinion, a step in the right direction, as he considered that no device of this nature could be of much service unless it safeguarded the speed of the engine (within reasonable limits) throughout the wind.

It was rather unfortunate that Mr. Paul had not made reference to any tests that might have been carried out to prove the efficacy of the Walker controlling gear. It would be interesting to have information on the following points:—

(1) At what point in the shaft did the controlling gear begin to safeguard the speed of the engine?

(2) Did the controlling gear, from the moment when it commenced to exercise its proper function, closely safeguard the speed of the engine to the end of the wind?

(3) To what extent was the cage speed restricted by the controlling gear when men were being lowered into the pit-bottom?

Mr. William Walker (H.M. Inspector of Mines, Edinburgh) said that he did not wish to express any opinion on the relative merits of the apparatus described by Mr. Paul, because eventually he might have to sit in judgment upon it. He might say, however, that he had seen the gear in actual use; and, so far as he was able to see, the combination of the overwinding preventer and the speed-controller appeared to him to provide an arrangement which complied with the new Mines Act. He would like to impress seriously on everyone who had anything to do with the management of collieries the very great risk that would be run by applying any overwinding preventer without a speed-controller on some of the winding-engines in Scotland. If there were no speed-controller for the purpose of reducing the speed when the cage reached the surface or the bottom, and the brakes were suddenly applied, he was certain that there would be great probability of an accident occurring. He entered into this discussion with the view of warning anyone who adopted these overwinding preventers to bear in mind what he had said. In his opinion, the present winding-engines ought

in every case to be very carefully examined, so as to ascertain whether they were capable of withstanding the strain which would be put upon them. He did not think, because they had got so many winding-engines of the description to which he had referred in Scotland, that it was a reason why these controllers should not be adopted. He quite believed that they should, but, at the same time, he thought that they must be used with every possible precaution so as to prevent a serious collapse of the brake-rims or drums.

Mr. JOHN PAUL (Lochgelly), in replying to the discussion at the last meeting,* wrote that Mr. Barclay was somewhat hasty in stating that the gear "would not meet all the requirements in the general run of collieries." The arrangement for controlling a wrong-direction start was practically instantaneous, as the trigger was worked direct from the cage; and, if the cage travelled an inch beyond the predetermined point, the gear acted instantly. The cage in this case was allowed to travel 2½ feet above the level of the plates before the emergency gear was brought into action. Numerous tests had been made with wrong-direction starts, and the cage, on the average, came to rest within a distance of 2 feet after the gear had commenced to act; that was to say, the cage was only 4½ feet above the plates. Of course, as stated in his (Mr. Paul's) paper, the predetermined point might be fixed anywhere, so as to suit the various wishes or requirements of the user.

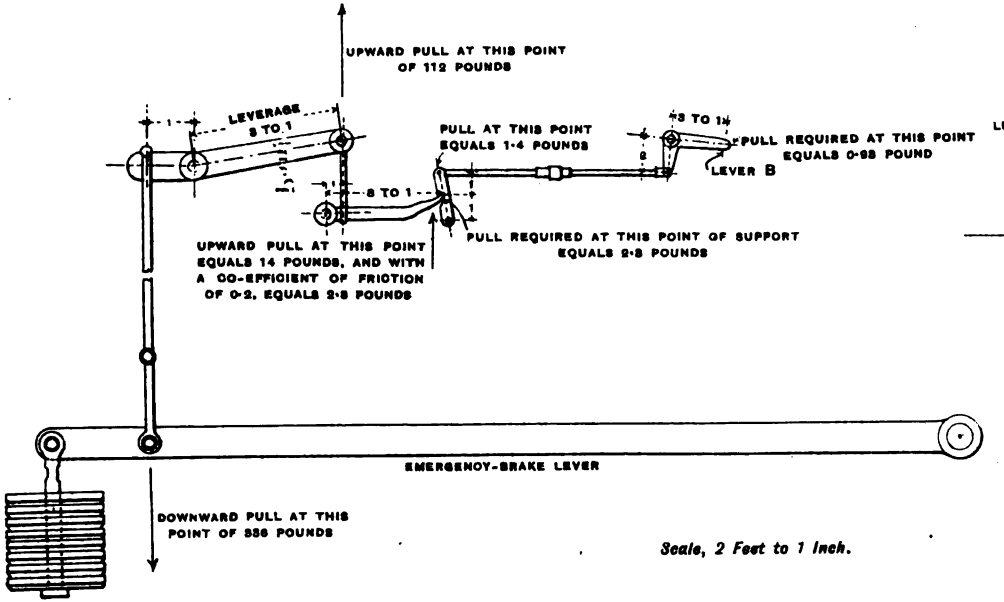
Mr. Barclay had evidently misunderstood the spring-pin arrangement. It was simply a device which permitted the driver to have the full control of his throttle at all times. The driver did not require just to "hit the mark," as he was warned by the bell, and could also see by the depth-indicator, when he was near the mark.

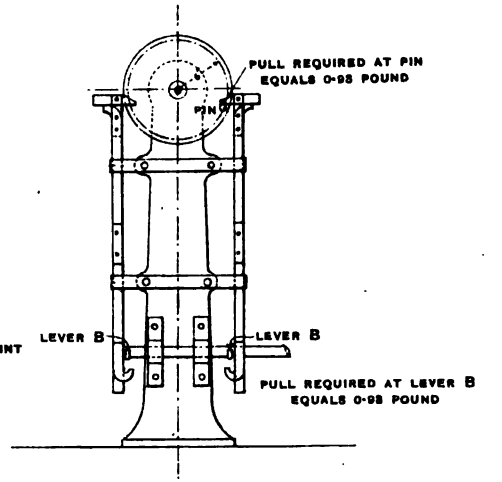
As Mr. Barclay had stated that he did not quite understand the reference to the strain on the indicator-shaft being very slight, owing to the leverage of 72 to 1 between the trigger-shaft lever and the weight, and as this matter might not have been made perfectly clear, he (Mr. Paul) submitted a sketch (Plate VII.), from which it would be seen that a load of 3 hundredweight on the brake-lever threw a strain of about only 1 pound

* *Trans. Inst. M. E.*, 1912, vol. xliii., page 57.

To illustrate Mr John Paul's reply to the discussion on his Paper on "The Walker Overwinding-prevention Gear," etc. VOL XLIII. PLATE VII.

SKETCH ILLUSTRATING LEVER ARRANGEMENT.


UPWARD PULL AT THIS POINT OF 112 POUNDS
LEVERAGE 8 TO 1
PULL AT THIS POINT EQUALS 1·4 POUNDS
3 TO 1½
PULL REQUIRED AT THIS POINT EQUALS 0·93 POUND
LEVER B
8 TO 1
UPWARD PULL AT THIS POINT EQUALS 14 POUNDS, AND WITH A CO-EFFICIENT OF FRICTION OF 0·2, EQUALS 2·8 POUNDS
PULL REQUIRED AT THIS POINT OF SUPPORT EQUALS 2·8 POUNDS
EMERGENCY-BRAKE LEVER
DOWNWARD PULL AT THIS POINT OF 336 POUNDS



Scale, 2 Feet to 1 Inch.

and.ᵐ Reid & Comp.ʸ L.ᵗᵈ Newcastle upon Tyne.

on the pin in the clutch-plate, and that the compounding of the leverage was independent of the pin movement required to release the trigger; the torsion on the indicator-shaft was also decreased by increasing the leverage.

The speed-controller was designed specially to prevent the dumping of the cage in the pit-bottom, and did effect that purpose. During a test, it was tried at different speeds, and pulled up the engines at 3, 2, and 1 revolution respectively, from the pit-head, and allowed only of a safe landing speed. The governor was set to work at variable speeds, and the sleeve rose proportionately to the speed of the engines. The gear was so designed that there must be a gradual reduction in the speed towards the end of the wind.

Since the reading of the paper, a two-speed arrangement had been fitted, worked by a small handle from the driver's platform, which permitted of a fast speed when winding coal, and of a slow speed when winding men. The controller was meant only to take charge of the last fifth of the wind, although it was quite a simple matter to arrange it so as to control the speed during nearly all the wind; but he (Mr. Paul) did not consider that necessary, as he desired as little restriction as possible, consistent with safety.

The emergency gear could stop the engines when running wild, without excessive shock, within $2\frac{1}{2}$ revolutions, and as the controller was in gear for about twice that number of revolutions, he considered that there was a large margin of safety, more especially when the fact that steam must have been shut off before the engines ran into the range of the speed-controller was taken into consideration.

In practice, the reversing gear worked in the way that Mr. Barclay considered desirable, namely, the throttle was closed first, and, after the steam was cleared between the throttle and the cylinder, the valves slipped gently into the central position. No undue compression took place, and the emergency gear brought the engine to rest more quietly than was usually the case by hand.

With reference to Mr. Barclay's statement, that the claim that the driver could still have control of the engines after a trip-out was a suggestion of weakness: he (Mr. Paul) had heard of an accident with a well-known overwinding-prevention gear

(which did not allow of the engineman using his levers after the gear had acted), that might have been prevented if the engineman had been able to use his levers. This provision was specially made in the Walker gear, in order that such an emergency could be met. It might be fairly claimed, therefore, that this provision added to the efficiency of the gear, whilst leaving it perfectly independent of human control.

In reply to Mr. James Black, for pits of moderate depth, he (Mr. Paul) thought that the overwinding-prevention gear, without the speed-controller, provided ample protection. To suggest that the engineman could make the gear unreliable by deliberately putting on steam after he had been compelled to shut it off, as Mr. Black had suggested, was tantamount to saying that the engineman could render any gear inoperative if he took means to do so. Taking Mr. Black's questions in the order named, he (Mr. Paul) begged to submit the following replies:—

(1) It was within the power of the management to fix the exact point in the shaft at which the controlling gear began to safeguard the speed of the engine, so as to suit the conditions of the pit.

(2) The controlling gear closely safeguarded the speed of the engine from the commencement of control to the end of the wind.

(3) The cage speed could be restricted to any speed desired.

All those who had seen the gear in operation (including a large number of the members) had expressed themselves as being highly pleased with it, on account of its simplicity, reliability, positive action, and the absence of complicated parts. This gear had been in action for demonstration purposes on more than a hundred occasions, and it had always given complete satisfaction. It was a curious fact that the two gentlemen who had so adversely criticized the gear, had never seen it in operation.

DISCUSSION OF MR. HENRY BRIGGS'S PAPER ON "TESTING FOR FIRE-DAMP AND BLACK-DAMP BY MEANS OF A SAFETY-LAMP."*

Mr. C. J. Wilson (Edinburgh) said that the advantages of the loop consisted in the size and intensity of the cap which appeared over the de-luminated flame; the device appeared to be of use chiefly to the fireman or other colliery official responsible

* *Trans. Inst. M. E.*, 1912, vol. xliii., page 64.

for the ventilation. But at least equally important was the possibility of a closer study of the cap under a variety of conditions which were likely to be met with in mines. Changes in the appearance of the larger cap were more readily observed than was possible with the cap over the reduced flame; changes in the composition, in the pressure, or in the temperature of the atmosphere, or in two or all of these, and their relation to the cap, could thus be studied more exactly.

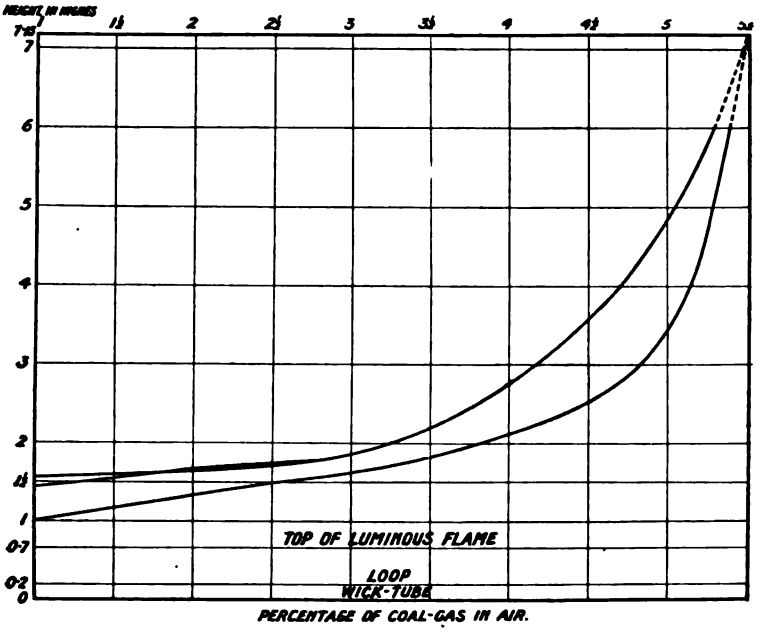


DIAGRAM SHOWING THE APPROXIMATE SHORTENING OF THE COAL-GAS CAP DUE TO AN INCREASE OF PRESSURE OF 13 INCHES OF WATER, EQUAL TO 887·77 FEET OF AIR OR 0·469 POUNDS PER SQUARE INCH IN THE SURROUNDING ATMOSPHERE. NO LAMP-TOP USED; LOOP OF NO. 22 GAUGE COPPER WIRE (½ BY ⅛ INCH); TEMPERATURE, 56° TO 61° FAHR; SATURATION, 87 TO 93 PER CENT.

The figure in the text illustrated the effect on the height of the cap of a change from atmospheric pressure to one of 0·469 pound to the square inch. The upper curve showed the total height of the flame and cap under atmospheric pressure, the flatter line in its lower part being copied from Mr Briggs's observations; the lower curve gave the height of the flame and cap under this pressure.

The atmosphere surrounding the lamp and forming the cap consisted of a gaseous mixture of air and coal-gas, a familiar

and satisfactory substitute for one containing fire-damp. The lower explosive limit of this coal-gas was fairly regularly 8·75 per cent.

In themselves the differences of the heights of the caps were most striking at the higher percentages. With 4½ to 5¼-per cent. mixtures they were well over an inch, while at the more important percentages of 1 to 4, these differences were comparatively small, under half an inch. At 2½ per cent. the normal cap and flame together were 1¾ inches high; under the pressure of 13 inches this became only about ¼ inch lower—that was, a decrease of a seventh of the total height due to that pressure. This was appreciable, but not serious.

But looking at the curves in another manner, the differences were more striking, and seemed to establish an important fact. When working under this pressure, the presence of 4⅞ per cent. of gas was indicated by a cap, which stood for 4¼ per cent. of gas in a mixture under atmospheric pressure, an error of over ½ per cent. In the steeper parts of the curve, the difference seemed to become rapidly less; perhaps the mixture even had a slightly lower explosive limit when under pressure. On the other side, say with a cap that would indicate 3½ per cent. of gas present, the error—when working under pressure—was also over ½ per cent.; 3½ should really be 4⅛ per cent. And going lower yet among the percentages of gas more frequently met with, and taking a cap just over 1½ inches high (always including the flame), and indicating under atmospheric pressure the critical 1¼ per cent., when under a pressure of less than half a pound to the square inch, the cap represented 2¾ per cent. of gas present. This pressure corresponds to only 888 feet of depth, without taking into account the complication through artificial ventilation.

Greater pressure seemed to still further reduce the height of the caps. Further figures were, however, not yet available, although the curves and the inferences to be drawn from them were significant enough to justify a very exhaustive series of experiments. He had now constructed apparatus which permitted of a steady pressure up to about 4 feet of water; the lamp and the hygrometer were enclosed airtight, but there was free access to the handles of the pricker and the loop.

The writer hoped at a future meeting of the Institute to lay

before the members more complete data than these first results of about 150 observations, together perhaps with an account of the effects of different temperatures and description of the apparatus used.

Prof. CHARLES LATHAM (Glasgow University) said that, in view of the early coming into operation of the Mines Act of 1911, the subject of Mr. Briggs's paper was one of the greatest importance, and one which must appeal very strongly to all connected with the management of mines. Should Mr. Briggs's contention—that the addition of a small copper wire to the fittings of an ordinary safety-lamp rendered it possible to detect readily by its use quantities of fire-damp and black-damp when such were present in mine air in only the very smallest percentages—prove true in practice, then he (Prof. Latham) felt sure that not only this Institute, but the whole mining industry, would be placed under a deep debt of gratitude to him for his valuable discovery.

With a view to verifying, or otherwise, Mr. Briggs's contention, and also the results of his observations thereon, Mr. George Hunter and he, during the past few days, had carried out a series of experiments with copper-wire loops similar in size and construction to those used by Mr. Briggs, and as nearly as possible under conditions similar to those which he employed. He (Prof. Latham) regretted to say that the results of these experiments had been anything but satisfactory from the point of view of proving the practical utility of a copper loop as a means of testing the nature of the air in a mine in conjunction with the flame of an ordinary safety-lamp.

It would be noticed that Mr. Briggs used in his lamp a mixture of oil consisting of 3 parts of colza and 1 part of paraffin. Such a mixture was found in his (Prof. Latham's) experiments to be most unsatisfactory in burning, owing to the charring of the wick. In his opinion, a much better mixture was 2 parts of colza to 1 part of paraffin, in which case the charring was reduced to a minimum.

Considerable difficulty was experienced in preventing the wire loop from being bent and pushed out of its true position when in use, and it was interesting to speculate what the result would be when the lamp was passing through the hands

of the average colliery lamp-cleaner. In this respect he (Prof. Latham) would like to know Mr. Briggs's reason for using so fine a wire, for, to the speaker, it appeared far too fragile to keep in anything like the necessary shape, position, and condition when in daily use underground.

Using mixtures of coal-gas and air containing from ¼ to 1½ per cent. of coal-gas, as used by Mr. Briggs in his experiments, both he and Mr. Hunter found it quite impossible to discern any trace of a cap, other than that which was due to the fuel, which was, of course, equally visible in pure air. Mr. Briggs stated that he obtained quite distinct and easily measurable "gas"-caps, the sizes of which he gave, for similar mixtures. He (Prof. Latham) was inclined to think that such caps as Mr. Briggs had observed were not "gas"-caps, but simply fuel-caps, due to the cooling action of the wire loop, and possibly to the insertion of the loop into the flame at a wrong height: for the results of the experiments carried out by him and Mr. Hunter proved quite clearly that the swinging of a wire or loop into the flame in pure air produced, under such conditions, an enhanced size of fuel-cap, this being more pronounced the higher the wire or loop was from the wick in the flame.

Did not this account for the flattening in the curves shown by Mr. Briggs on page 68, for which phenomenon he admitted his inability to give any explanation? If in his experiments the loop was in every case swung into the flame at the same height, then the fuel-cap would be always the same height in each case, whatever the percentage of inflammable gas might be —provided that such percentage were below that necessary to show a gas-cap in addition. Mr. Hunter and he did not find such a gas-cap to be present until over 1½ per cent. of inflammable gas was present. On examining Mr. Briggs's diagram (Fig. 3, page 68), it would be noticed that it was just at this point, namely, when over 1½ per cent. of inflammable gas was present, that the flattening ended and a gradual rise began.

He (Prof. Latham) would like to ask Mr. Briggs at what height above the wick when testing for fire-damp the loop should be swung into the flame: for, although he had fixed very exactly the lowest and highest possible positions of the loop, he had said nothing as to whether it should be swung in at the lowest, highest, or any intermediate position. He (Prof. Latham)

might say that he and Mr. Hunter had found it to be a matter of the utmost importance to swing in the loop at the right position.

In his remarks (page 77) on testing for black-damp by means of the loop, Mr. Briggs had made the following statement:—"It is . . . . necessary to say that less than 1 per cent. of fire-damp will destroy the utility of the loop as a means of detecting air which is inadequate under Section 29 (3)." This meant, of course, that black-damp could not be detected in the presence of even very small percentages of fire-damp, hence the loop was of no value in any mine containing a mixture of fire-damp and black-damp for the detection of the latter, and could only be used for such a purpose in those mines where fire-damp did not exist. Now he (Prof. Latham) maintained that the loop would not indicate the presence of such small percentages of fire-damp as were required to upset the detection of black-damp, and it appeared to him to be quite possible to certify by using the loop that a mine was quite within the legal limits as regarded the proportion of oxygen, when as a matter of fact such was not the case, owing, of course, to the admixture with the black-damp of such small percentages of inflammable gas that the loop would not detect them.

It was to be noticed further that in all his experiments Mr. Briggs had used what he called "standard black-damp." This was quite a new term to him (Prof. Latham), and he was fully of the opinion that no two samples of black-damp taken from different parts of any mine would be found to have exactly the same chemical composition—more especially so in mines in which there were large wastes.

On page 75 Mr. Briggs had stated: "It is certain also that black-damps differing from the standard composition have different effects"; consequently black-damps differing in composition from one another would have different effects also. Mr. Briggs had got over this difficulty by "making the loop suit the conditions under which it had to work." But he (Prof. Latham) would like to know whether in any two tests to be made in a mine during an examination the conditions as regards composition were likely to be the same. If not, then to get the right result the experimenter would require to use a different loop for each test, and in order to know with anything like accuracy whether

he was using the right loop or not (or, in fact, what particular loop to use in each case), it would be necessary for him to make a chemical analysis of the black-damp before he could make the loop test at all.

Possibly it might be contended that all that was required was, as Mr. Briggs had stated on the same page, to know the *average* composition of the black-damp in each mine. Was this, however, practicable? Was there such a thing as a fixed average composition? Was not the average a constantly varying figure? What might be the average to-day was not the average to-morrow or the day after, and hence it would be seen how utterly erroneous the results obtained in such a way were likely to be.

On page 74 Mr. Briggs had stated that—

"In the ordinary supervision of ventilation, however, it would not seem essential that the actual percentage of black-damp in the air be known, so long as the officials underground are able to make sure by some simple means, that the air is in 'a fit state for working or passing,' having regard to the criteria of Section 29 (3) of the Act."

Surely in this he was wrong, for did not this very Section 29(3) state that "for the purposes of this section, a place shall not be deemed to be in a fit state for working or passing therein if the air contains either less than 19 per cent. of oxygen or more than 1¼ per cent. of carbon dioxide." How was it possible to obtain this information, unless not only the exact percentage of black-damp present, but also its exact composition as well, were known? He (Prof. Latham) was afraid that anything depending on such a rough-and-ready principle as that of average composition for its construction would not meet the legal enactment. Further, with regard to the standardization of the flame used by Mr. Briggs when testing for fire-damp in the presence of black-damp, it was the speaker's opinion that while such a method might be of use in testing in an atmosphere of known composition, such as Mr. Briggs had in his laboratory, it would be of no value in testing in an atmosphere of unknown composition in the mine, and that any reliance placed on results so obtained in practice might easily lead to very serious consequences.

In conclusion, he was afraid that he must also disagree with Mr. Briggs in the statement that his loop was a modification of the Cunynghame-Cadman device. Mr. Briggs's loop acted on

quite a different principle, one which in his (Prof. Latham's) opinion was thoroughly unscientific and opposed to well-established facts. Mr. Briggs masked the luminosity of his flame by reducing its temperature, which at once decreased the height of the gas-cap, for the hotter the flame the larger would be the caps, and, consequently, the smaller the percentage of inflammable gas that could be detected. As before pointed out, this lowering of the temperature set up increased heights of fuel-caps, which as a consequence could readily be mistaken for "gas"-caps. In the Cunynghame-Cadman device there was no lowering of the temperature—simply a masking of the luminosity.

Mr. D. M. MOWAT (Coatbridge) said that the question of the difference in height of a cap under different pressures of atmosphere was new—at least, it was new to him. If it proved to be correct, it would be a very serious source of difficulty, more especially to Inspectors of Mines in prosecuting firemen. From a glance at the diagram he saw that 1¼ per cent. on the high grade represented 2½ per cent. on the low grade. Either percentage might be right, and indeed it was quite possible that they were both wrong, but exactly how the Sheriff would decide the matter he did not know. In this connexion he would like to draw attention to papers* communicated to the Institute by Prof. Thomas Gray, of the Royal Technical College, Glasgow. Mr. Forgie and he (the speaker) were associated with Prof. Gray in his experiments, which were made privately at the outset in dealing with evidence before the Royal Commission on Mines, but the figures were ultimately given to the Institute. Very exhaustive tests were made in a pit, 960 feet deep, and experiments with percentages of gas from caps at less than a ¼ of an inch right up to inflammable gas. About the same time experiments were also made in the Royal Technical College, and the results there, it was interesting to note, were exactly the same as in the pit 960 feet deep.

Mr. C. J. WILSON said that, whatever doubt there might be about the effect of increased pressure, it was certain that an

* "Fire-damp: its Composition, Detection, and Estimation," and "Analyses of Samples of Air from Representative Mines in Scotland," by Thomas Gray, D.Sc., *Trans. Inst. M.E.*, 1910, vol. xxxix., pages 286 and 305.

increase of pressure gave a decrease in the height of the cap, and that different pressures yielded different results. This could only be called in question by showing his (Mr. Wilson's) whole mode of proceeding to be mistaken, which he thought would be impossible. He would gladly put his methods to the test before the Institute, and in this way, and by further experiments, it could be shown whether there was any shadow of doubt in the matter.

With reference to the loop, he did not wish to anticipate Mr. Briggs, who was abroad; but some of the points raised concerned simple facts, and might as well be answered at once. The mixture of three parts of colza and one of paraffin was one that was in general use. Experiments had been made with the loop, using not only this mixture, but also a variety of other fuels, the results being correspondingly similar in regard to the effect of the loop. He believed that Mr. Briggs left no doubt in his paper that the shape or material of the loop did not affect the principle or its application. Speaking for himself, he (Mr. Wilson) had laid stress on this fact; and, although Mr. Briggs might have definitely adopted the loop in its present shape, there might well be room for experiments to fix on a different construction.

This want of rigidity he (Mr. Wilson) believed to be, not an objection, but an advantage, as a damaged loop was easily bent right again. But damage could only be done to the loop while the lamp was open, generally when it was being put together. The fireman would see at a glance, before taking his lamp away, whether the loop was in order or not; if necessary, he could have his loop re-opened, and could sort the loop on the spot without trouble. When underground, where the lamp could not be opened, after once being closed, there would be no occasion for sorting the loop: no damage could be done to it, except by quite extraordinary means and purposely.

As to experiments with mixtures containing 1 per cent. of gas and giving distinct gas-caps with the loop, if anyone interested in the subject cared to call at the Heriot-Watt College, Edinburgh, they could themselves experiment with different types of lamps and with different apparatus: their experiments would prove that what Mr. Briggs claimed for the loop was correct. They would be able to see the gas appear when a

mixture of gas and air was admitted to the lamp and disappear when the gas was excluded, the same air, but without the gas, being led to the lamp. This change could be repeated any number of times, with any percentage of gas. For fire-damp Mr. Briggs had given definite instructions as to the position of the loop in regard to the flame. In the pressure experiments the loop used was in every case inserted half an inch below the top of the ordinary luminous flame.

Prof. DANIEL BURNS (Glasgow) said that he agreed with the remark made by Mr. Mowat as to the facility with which experiments of this nature could be carried out in the laboratory, but the conditions were somewhat different in the mine. If the object was to impart a distinctive colour to the cap formed by the burning gas, this could be attained, without tinkering with the flame, by saturating the wick in sodium chloride or lithium chloride, or by adding ethyl chloride to the fuel. The first ingredient imparted a yellow colour to the cap, the second a red, and the third a green; but the two former caused a troublesome incrustation to form on the wick, while the ethyl chloride, being very volatile, tended to produce a somewhat large fuel-cap. None of these methods was, so far as he could see, likely to be of any special service in practical testing for gas in the mine.

Mr. D. M. MOWAT said that he did not know whether it had any bearing on the point, but he might instance the case of the internal-combustion engine. With that engine a better expansion was got with the higher compression, but in the diagram it appeared that the shorter the flame the higher was the pressure indicated. He would merely point out that the opposite held good of the internal-combustion engine.

Mr. C. J. WILSON said that in that case all the heat was obtained, and it did not pass away.

Mr. JAMES BLACK (Airdrie) said that it seemed to him that the results of Mr. Wilson's investigations with regard to the length of caps obtained in atmospheres of different densities were perfectly logical. A cap was produced on the flame of a safety-lamp by the combustion of the molecules of fire-damp which were within the high-temperature heat-zone of the flame.

The number of molecules of fire-damp contained in a unit-volume of a mixture of fire-damp and air was not a constant for a given percentage of fire-damp, but varied directly as the pressure to which the mixture was subjected. From this it was to be expected that in an atmosphere of higher pressure than the normal, such as existed in a deep mine, the molecules of fire-damp would be a less distance apart for a given percentage of fire-damp, and consequently the combustion of the molecules of fire-damp would extend to a greater distance from the flame, and thus produce a larger cap.

The further discussion of the paper was adjourned.

The following paper, by Mr. James Black, on "Overwinding-prevention and Controlling-gear for Colliery Winding-engines, with a description of the Inglis Controller," was then read:—

OVERWINDING-PREVENTION AND CONTROLLING GEAR FOR COLLIERY WINDING-ENGINES, WITH A DESCRIPTION OF THE INGLIS CONTROLLER

By JAMES BLACK.

Introduction.—Clause 40 (Sub-section 2) of the Coal Mines Act, 1911, stipulates that if a shaft is more than 100 yards in depth, the winding machinery shall be provided with an effective automatic contrivance to prevent overwinding.

An ideal controller should be capable of performing the following operations:—(1) The prevention of an overwind or an underwind; and (2) the control of the speed of the cages throughout the entire wind. Most of the controllers now in use are very reliable as regards the prevention of overwinding, but the same cannot be said of them as regards underwinding, which presents a more difficult problem.

In the raising of coal there is a practical limit beyond which it is not desirable to reduce the cage speed when nearing the completion of the wind, from which it appears that a controller arranged to permit of coal-winding cannot prevent an underwind.

In the new type of controller described in this paper dangerous underwinding is prevented, during the time when men are being raised or lowered, by the engineman making a simple adjustment on the controller; and the writer considers that some such alteration will be essential in all controllers designed to prevent underwinding when men are being lowered into the mine. A controller which prevents overwinding will also prevent underwinding, provided that the passage of the cage is unobstructed for some distance below the lowest hanging-on point in the shaft. This may seem an easy way out of the difficulty of preventing underwinding when a controller which prevents overwinding is in use, but it is not, as keeping a pit open for some distance below the hanging-on point presents several difficulties, which are well known.

Accidents resulting from the use of controllers are likely to occur, unless great care is taken when fitting and adjusting the

brake which is brought into operation by the controlling-gear. When a winding-engine is running at a high speed, the large mass comprising the moving parts contains a great amount of kinetic energy, which, if arrested quickly by the brake, causes a considerable strain on the machinery. The practice of using a brake-wheel in conjunction with a controller is not to be recommended, as a terrific strain is thrown upon the keys which secure the wheel to the drum-shaft. The most efficient and safest method is to have a brake-rim fitted on each drum.

There is a tendency at the present time to overload the brake-lever, with the object of stopping the engine as quickly as possible after the controlling gear comes into operation. This is a mistake, and only serves the purpose of subjecting the machinery to a much greater strain than need be. At the points where the controlling gear comes into operation for an overwind or an underwind, the cages will, after the brake has been applied, travel a less distance with a given load on the lever than they would at any other point in the shaft where the gear may be brought into operation. It would appear, therefore, that the load on the brake-lever need only be sufficient to ensure the prevention of an overwind or an underwind. When the brake is adjusted in this way, the cages will then, if the controlling gear were to come into operation at, say, mid shaft, travel the maximum distance permissible with the controlling arrangement before being brought to rest, and this is as it should be.

The Inglis Controller.—The writer had recently the opportunity of making some tests with the Inglis controller, which is fitted on the winding-engines at the No. 12 Pit, Holytown Colliery, belonging to Messrs. James Nimmo & Company, Limited. A description of this controller, which possesses some special features, may be of interest to the members.

The Inglis controller is a simple and efficient device to prevent both overwinding and dangerous underwinding at collieries. Being entirely controlled by the speed of the engine, it takes charge of the wind from beginning to end. It also acts instantly in case the engine is started in the wrong direction. This gear (Figs. 1, 2, 3, and 4, Plate VIII.) consists of a cast-iron box used as a housing frame for carrying the shafts, etc. One governor only is used; it is spring-loaded, and is combined with a balance-

weight. The governor is driven by a square shaft, which revolves a sleeve in the body of the governor, to which a bevel-wheel is attached. There is also fixed in a lower part of the body of the governor a gun-metal screwed nut in which a screw-shaft causes the governor to travel during the wind from one end to the other of the box, the weight of the governor being carried on a guide at the bottom of the box. To the rising and falling sleeve of the governor is attached a double lever supported in a fulcrum and projecting beyond the fulcrum on one side and beyond the governor on the other side. On the side beyond the fulcrum is fixed a steel catch to engage with a toothed rack, and on the other side of the governor a balance-weight is attached by a bolt, and made so that its position can be adjusted to suit the requirements of the governor. At each end of the box at one side is fixed a perpendicular arm or wyper working on a pin at the bottom, and the two wypers are joined together by two flat bars—one on each side, with suitable bolts holding them together. Between the two bars previously mentioned is fixed a steel rack, over which the catch attached to the double lever passes as the governor travels along the box in either direction. At each end of the rack is fitted an adjustable piece with stepped notches. The wyper at each end is fitted at the top with a set-screw facing the direction of the travel of the governor, and this screw is adjusted to suit exact stopping conditions, the point of the screw being advanced until it touches the catch attached to the governor lever, when the engine is at rest at the end of the wind. To this rack and wypers are attached a shaft with double wypers and connecting-rods with slots, to which also the trip-lever is attached. This is arranged so that the trip-lever always rises, without reference to the direction in which the rack is moved by the governor-lever catch. The whole arrangement may be operated by gear and shaft from the engine, as shown in Fig. 4 (Plate VIII.), or it may be operated by a pitched chain from the engine-shaft.

The working of the gear is as follows:—When the engine commences a wind, the governor is moved along the box by the screw-shaft, and the speed part of the governor is driven by the square shaft. So long as the engineman works his engine in the predetermined manner, the gear does not come into operation. If, however, the engine attains a higher speed during

the wind than that predetermined, the governor-sleeve rises and depresses the double lever and catch, and causes the catch to come into contact with the rack, which immediately releases the trip-piece holding the weights; the steam is instantly shut off, the brakes are applied, and the engine is stopped. If towards the end of the wind the engine has not been reduced in speed to what is considered safe at that part of the wind, the catch comes into contact with the higher stepped part of the rack, which releases the trip-piece and stops the engine in the manner previously described. Should the engine be started in the wrong direction, the catch part of the governor-lever being in contact with the set-pin at the top of the wyper, the slightest movement releases the trip-piece and the engine is stopped.

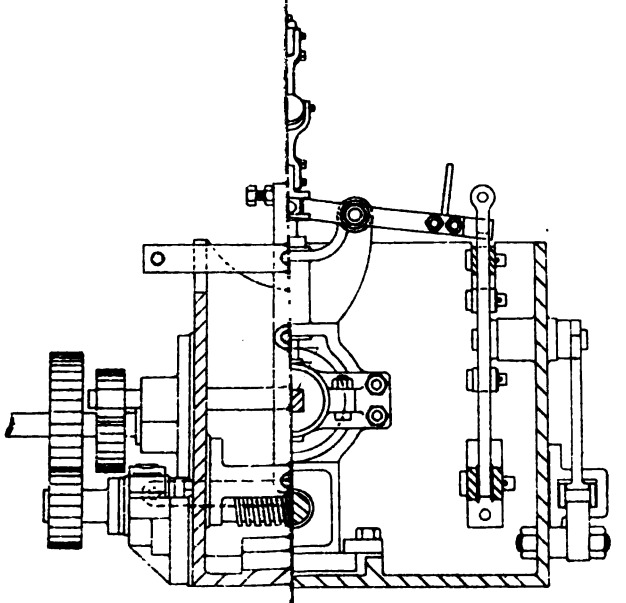
To prevent an underwind, it is only necessary to alter the gear to the extent of putting a small weight on a pin on the catch side of the governor-lever. This weight causes the catch to come into contact with the rack at a less speed than when winding coal. The engineman will therefore require to wind the men at a slower speed, in order to prevent the gear from coming into operation. It also ensures that he will reduce his speed at the last revolution to what is absolutely safe, otherwise the gear would come into operation. It is only necessary, of course, to remove this weight in order to start winding coal in the ordinary way.

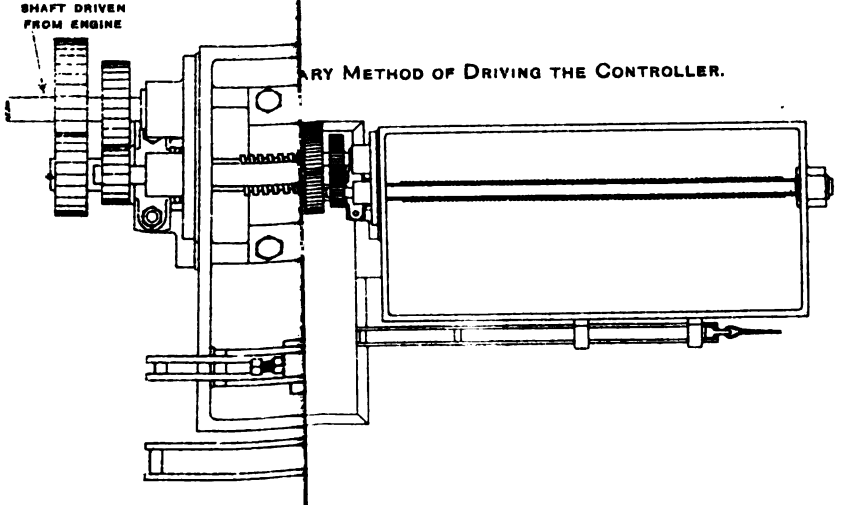
The engines on which the controller is fitted have cylinders 18 inches in diameter, and are supplied with steam at a pressure of 80 pounds per square inch. There are two drums, one 12 feet and the other 8 feet in diameter, the depth of the wind being 792 and 516 feet respectively; the maximum speed of the wind, as determined by the management, is at the rate of 60 revolutions per minute before checking commences. The controller has been tested exhaustively by the engineers and officials of the colliery, the following tests, amongst others, having been carried out:—

(1) The engine was started with the larger drum unwinding, and full steam was admitted. When the engine reached 70 revolutions per minute, at the eighth revolution the governor acted and brought the engine to a stop in 3 revolutions.

(2) The engine was allowed to run at its predetermined speed of 60 revolutions per minute without any checking, when the

2.—End Elevation.





ary Method of Driving the Controller.

governor-catch came into contact with the higher stepped part of the rack, and brought the engine to a stop in 2¼ revolutions.

(3) The engine was started in the wrong direction with full steam on, and it was almost instantly brought to a standstill. The height of the cage above the pit-head plates was found to be 2 feet 1 inch. This height can, of course, be increased by an adjustment of the set-pin.

(4) Several tests were made in order to ascertain the efficiency of the controller in preventing dangerous underwinding. It was found that whenever the speed of the rope exceeded 350 feet per minute at the beginning of the last revolution of the wind, the controller acted instantly and stopped the engine.

The connexion between the trip-piece holding the weights and the weights themselves in this particular instance is a small wire rope, and either this contrivance, or rods and wypers, may be used, according to engineroom arrangements. The time taken by one man to replace the gear after use is about 3 or 4 minutes.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE,

APRIL 13TH, 1912.

MR. M. W. PARRINGTON, PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, and reported the proceedings of the Council at their meetings on March 30th and that day.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. EARLE BEST, Colliery Manager, 12, Station Road, Hetton-le-Hole, County Durham.

Mr. CECIL WILLIAM CHATER, Mining Engineer, Mining and Metallurgical Club, 3, London Wall Buildings, London, E.C.

Mr. FREDERIC CHARLES GARRETT, Lecturer in Chemistry, Armstrong College, Newcastle-upon-Tyne.

Mr. HENDERSON GIBSON, Colliery Manager, Backworth Colliery, Backworth, Newcastle-upon-Tyne.

Mr. EMIL RECKLING, Mechanical Engineer, 49, Cannon Street, London, E.C.

ASSOCIATE MEMBERS—

Mr. JOHN ELCOATE, 16, Marton Road, Middlesbrough.

Mr. ERNEST HAVILAND HILEY, North-Eastern Railway Offices, Westgate Road, Newcastle-upon-Tyne.

Mr. ISAAC BOWMAN ROGERS, 8, South Street, Newcastle-upon-Tyne.

ASSOCIATE—

Mr. STANLEY SHARPE MAGEE, Mining Surveyor, 6, Kensington Terrace, Dunston Gateshead-upon-Tyne.

DISCUSSION OF MR. JAMES LOMAX'S PAPER ON "THE MICROSCOPICAL EXAMINATION OF COAL, AND ITS USE IN DETERMINING THE INFLAMMABLE CONSTITUENTS PRESENT THEREIN."*

Mr. JAMES LOMAX (Bolton) wrote that he was obliged to Mr. David Burns for the kind manner in which he had referred to the value of the paper in certain directions, especially as to its bearing on the origin of coal. He agreed that the numerous theories which had been held were to a great extent speculative, and not borne out by any substantial facts or observations. His object in his recent investigations had been to see *in situ* the various constituents, their form, ornamentation, if any, and their combination and position in the seam. In this direction, especially during the last few months, he had been very successful, thus bearing out all, and in most cases more than, he had ventured to say in his paper.

Mr. Burns had referred to the vegetation of the coal period as being of a rank character, with an abundance of spores. That statement was, in the majority of cases, quite correct with regard to the coals which he had examined from the Lancashire and Yorkshire coal-fields, and also from the North Staffordshire area. He had lately finished forty-one vertical sections of different seams, some of them being of a very large size, and every one bore out what he had already said, namely, that the majority of coals were made up of megaspores and microspores in a ground-mass of vegetable humus. It did not matter what seam was taken (from the Middle Coal-Measures was the rule), although the bottoms contained considerably less than the tops. This fact was only what would be expected when the geological and palæobotanical evidence was taken into account. One illustration out of many was as follows:—The roof of the Arley Mine, in the Bolton district, consisted of a shaly mudstone, which was crowded with plant-remains, mostly of a lycopodiaceous character, such as *Lepidodendron*, *Sigillaria*, etc., with here and there a *Calamites* or two, while the floor consisted of a seat-earth or "warrant" full of Stigmarian roots, which could in some cases be traced through the coal to a bole

* *Trans. Inst. M. E.*, 1911, vol. xlii., pages 2, 459, 462, and 606; and 1912, vol. xliii., page 88.

of *Lepidodendron* or *Sigillaria* in the roof. They were of various sizes, from 8 or 9 inches to more than 3 feet in diameter, and he had counted eleven in one place alone, in a space measuring about 16 by 8 feet. The most interesting specimen was a trunk lying on the top of the coal, which he had traced as far as he could, and found it was 114 feet from its base to the portion where the bifurcating branches commenced, these comprising another 25 to 30 feet. In the mass of branches were twigs and fructiferous branches, lying amongst which were numerous cones, some of them being 8 or 9 inches in length. The diameter of the trunk at the base (across its major axis) was 3 feet 4 inches by 1 foot 10 inches, whilst at the upper end it was 1 foot 6 inches by 4 inches, as it was naturally flattened. Examples such as these explained the reason of there being a greater amount of spores in the upper part of the seam. It would be obvious, in the earlier stages of the growth of the vegetable *débris* which now formed the coal, although the lycopods would be the dominant plants, that they themselves would be of a relatively small size compared with what they would become as time went on. They would not shed so many leaves, twigs, fruits, etc., as they would in the older stages, nor would they crowd out in the earlier stages other plant-life such as *Calamites*, *Sphenophyllum*, *Pteridosperms*, and the lowly fern plants, as they undoubtedly did in the older stages. What was observed, therefore, was only the natural result of such conditions. Many other points could also be brought to bear on the same assumption, such as the numerous bands of compressed leaves found in the Arley Bottoms; these were known to be so, for in many cases leaf-tissues could be made out with the higher powers of the microscope. Then they had as a rule more resinous bodies, *Amberites*, *Ovalites*, etc., in the lower portion of the seam than in the top; and assuming these to have been given off from the resin-glands of plants, which would ultimately be crowded out by the more dominant types, the bottom part of the seam was where they might be expected to be found.

He appreciated Mr. Burns' word of caution with respect to the eye being apt to see what the mind bade it see. Without fear of contradiction, he thought that during the last 20 years he had cut up more specimens of fossil plants, etc., from the Coal-Measures than any other person, and he had always been very

careful indeed in his assumptions; if they had not always met with the support of other investigators, they had not been contradicted. In his investigations on coal during the last 15 months, he had been very particular that all that he had seen could be seen by anyone else using the same means, and he did not think that in his paper he had exaggerated anything in the slightest particular. In the examination with the microscope of both vertical and horizontal sections, it would be found that there could hardly be any mistake in distinguishing the megaspores, because there were scarcely any two mines the megaspores from which had the same ornamentation on their outer edges. He was now engaged in abstracting whole spores from various coals, some of which were as perfect in form as when living.

With regard to Mr. Blackett's remarks, it was his (Mr. Lomax's) intention to carry his investigations further—in fact, they had not been stopped since the early part of last year; and since the publication of his paper a large mass of important and useful information had been obtained, which more than confirmed all that he had stated or suggested.

Mr. Blackett had raised the question as to whether there was any difference in the vegetable composition of a seam having a shale or mudstone roof and that of a seam having one of sandstone. So far as he (Mr. Lomax) had investigated the point, there was no difference. He had already given one instance where the mudstone roof of the Arley Mine was crowded with the prostrate remains of huge lycopodiaceous trees; and many instances of a similar character could be quoted, one of which was notable as supplying the largest and most complete lycopodiaceous trunk with branches that had been recorded, until the one discovered in the roof of the Arley Seam at the Hulton Collieries.* This was the specimen found in the Bensham Seam at Jarrow Colliery, and described and figured by John Lindley and William Hutton in their work on *The Fossil Flora of Great Britain*.† It was similar to that from the Hulton Collieries, described in a paper communicated to the Manchester Geological and Mining Society by himself nearly 2 years ago, but which unfortunately, owing to lack of the funds needed to

* See *Trans. Inst. M. E.*, 1909, vol. xxxvii., page 174.

† 1837, vol. iii., page 203 and plate 203.

cover the cost of the illustrations, had not yet been published. The specimens described by Lindley and Hutton were named *Lepidodendron sternbergii*; the length of the trunk to the point where the branches commenced was 39 feet, and the ramifications of the branches from the first bifurcation were 10 feet in the vertical direction and 13½ feet in the lateral direction. The trunk was flattened; it was 3 feet across at its widest part, and gradually tapered towards the top. The bearing that such illustrations had on the questions raised was, that after the deposition of the vegetable humus there came a quick subsidence, which caused the area covered by the dense lycopodiaceous forest to sink below water-level. The upright trunks would in consequence rot and ultimately fall, and, if the conditions were favourable, these trunks, branches, etc., would become embedded in the fast accumulating mud. The point of separation of the trunk from the bole was seen in the upper ends of specimens which had dropped out, sometimes with most disastrous effect to life, from the pot-holes which were so plentiful in the roof of many seams. If the subsidence occurred where the water became deep and comparatively still, little disturbance would take place in the removal of the prostrate trunks, etc., as from the first commencement of the subsidence mud would accumulate and form a receptacle or matrix, in which they would be embedded and ultimately buried. Where a seam had a mudstone roof, plant-remains would more often be found than in the case of a seam with a sandstone roof. A seam having a sandstone roof showed that the subsidence had not been great, possibly many large tracts having only been submerged through tidal effects, with a consequent paucity of fossils. This also accounted for the discovery of specimens embedded in strata far removed from a seam of coal. This process was still going on: in many places on the sea-coast there were to be found submerged forests, where the boles and roots of trees only were found, the trunks having been washed away to some other part or having rotted entirely away. A fine example of the remains of a Carboniferous forest was to be seen in Victoria Park, Glasgow, where there were many stumps with roots attached, prostrate stems, and branches; also a bed of ripple-marked sandstone, which was formerly continuous over the part that now showed the uncovered stumps. A splendid illus-

tration of the forest, etc., was included in Prof. A. C. Seward's *Fossil Plants.** A fine mudstone or shale roof, therefore, indicated that it had been deposited in relatively deep water as compared with a sandstone roof. Many black-shale roofs contained fish-remains, sometimes marine and at other times fresh-water, or both combined.

Prof. Bedson had admitted that the microscope had revealed the fact that coal was composed of a mixture of many substances, which the chemist already knew, and he had then thrown out a caution that they must not expect the microscope to yield too much information. He (Mr. Lomax) believed the microscope to be quite as useful and as accurate in determining the composition of coal as chemical methods—in many cases more so. When a chemist made an analysis of a sample of coal it was a destructive one; but, in the case of a microscopical analysis, the material, which could be prepared in various ways, either as opaque preparations, transparent preparations, or in any other way, could be kept as a permanent record. Prof. Bedson was quite right when he said that the microscope enabled one to see things and to give them names, the latter being a matter of detail only —the seeing of things in a slice of coal was the principal object in view. In the paper it was pointed out that many seams contained bands of a resinous nature, which if made into dust would be much more inflammable than any other part of the seam, and this fact he had verified over and over again. A striking illustration had lately been supplied to him. He had had sent to him four blocks of coal from the same seam, numbered only, without any indication of the vertical position of each block. The greater proportion of each of the blocks was microscopically different, and if chemically analysed would also show a great difference; but, by the microscopical examination, he found that one of them was composed of nothing but microspores and megaspores, while another was composed of a mixture of the above with a dense black ground-mass of a cellular character, the alveoli in which were undoubtedly gas-cavities, a fact proved by the method used to drive out the gas. Another block contained a band, 4 to 6 inches thick, full of the intensely resinous-looking bodies that he had named *Ovalites* and *Amberites*; this band contained no gas-cavities, and was of a lustrous appearance. When

* 1898, vol. i., frontispiece.

any of it was made into fine dust, it was not black, but brown; and if cut or ground, the mud produced was brown. If the dust was introduced into a gently moving current of air, the smaller particles were separated from the larger, and carried in suspension for a considerable distance. When mounted, the microscope revealed that the smaller and lighter particles were fragments of *Amberites*, with sometimes *Ovalites*, while the larger, and consequently the heavier particles, were found to be mostly portions of *Ovalites* and portions of the brown ground-mass. The band was shown in the section and also in the dust to be composed of a highly humid ground-mass, full of the resinous bodies named *Ovalites* and *Amberites*, with scarcely any spores. The other two portions of the seam contained many interesting structures, but nothing that looked so inflammable. Dust had been made from eight portions of the seam, and tested, the inflammability of the dust from the above-mentioned band being greatly in excess of dusts made from other parts of the seam. This was one of many cases, and it proved that the microscope could locate the inflammable bands, and show the form, size, etc., of the various bodies composing it.

Like Prof. Bedson, he (Mr. Lomax) had, on and off for nearly 30 years, tried to fathom the nature and constitution of the ingredients which formed the basis of coals, and he had almost given it up as a failure previous to the late disastrous explosion at Hulton Colliery; this occurrence caused him to renew his energy, with the results which had already been cited. He ventured to say that, with increased study and investigation, the microscopic examination of coal, and its allied shales (including oil-shales) and cannels (bastard and otherwise), would become of great value both commercially and scientifically. It would become quite as reliable as micropetrology was in the examination of rocks—the various bodies and substances occurring in coal would become as well-known as the rock-forming minerals in petrography. The term "resinous," or "resin-like," that he had used, was not perhaps exactly descriptive, but it conveyed the nearest definition of the bodies observed; probably the future would bring other definitions. He believed that the future investigator of the microscopic structure of coal* would be able to show the probable origin of the resin-like substances and the conditions

* The writer suggests that the term "Micro-coalologist," or some such name, should be used to indicate an investigator in this branch of science.

under which they were laid down. Beyond that, and, what was more important to Great Britain, nationally and commercially, a proper microscopical examination of coals and shales, based on scientific principles, would mean that many of our seams or parts of seams could be put to more economic uses than at present. Many portions of seams, now unworked or thrown into the gob, could be utilized and won at a profit, and many beds of shale, now looked upon as unfit for oil-extraction, would prove to be of commercial value. He thought that Prof. Bedson would agree that when any substance, whatever it might be, could be seen *in situ* amidst its surroundings, it gave one a general idea of its composition and its origin; but when those substances could be extracted, analysed, and found to be of the nature that the microscopic examination led one to believe, then it was fair to say that such investigations of coal could be made very useful. There was also this point—that if by examining any portion of a seam it could be ascertained whether it was cellular or inflammable, that is, likely to give off gas or inflammable dust, a forewarning was obtained of what to expect under certain conditions.

With regard to the use of the microscopic examination of coal in the correlation of our seams, he (Mr. Lomax) had had this in his mind for some years, and, from his recent work, felt confident that it could be made of great use. He believed that, as in ordinary petrology, such as the microscopic examination of igneous and plutonic rocks, etc., where the various rock-forming minerals, etc., contained therein could be determined, by a systematic examination of coals in the same way, which would be quite as reliable, the various constituents found therein, and also in the majority of cases their origin, could be determined. As mentioned in his paper, in the Plodder Seam there were bands of varying thickness, which showed characteristic structures common only to individual seams. If these structures happened to be confined to a certain position, where, through the methods of working, they were ground up into fine dust, as by coal-cutters, the dust so made was most inflammable. This fact he had confirmed over and over again since writing his paper. Of course, before one could be absolutely sure, much more work would have to be done, in order to ascertain the characteristic form of each kind of megaspore, how they occurred

in a seam, whether singly or in combination with other forms. In the numerous sections which he had lately completed, some were from the same seam taken several miles apart, but each coal from the same seam showed the same kind of characteristic structure, concerning the correlation of which there was no doubt.

With reference to the methods employed in the preparation of the sections, he had had to make numberless experiments in driving out the gas from the porous part of the coal, and in filling up the pores so that a section could be cut and made sufficiently thin for examination. In some cases it was a very tedious process, a preparation in most instances being in hand for 4 or 5 days or more. The principal point was the driving out of the gas and using a medium which would combine with the coal without generating air or gas-bubbles. He could now make almost perfect sections measuring 2 or 3 inches square, whereas formerly ½ or ¾ inch was as much as could be expected.

Mr. DAVID BURNS (Carlisle) wrote that he was no microscopist, and made no pretensions to having obtained different results from those of Mr. Lomax. He had, however, views of his own on the origin of coal, but, as the modern scientist had become nearly as dogmatic and as impatient of heresies as his clerical brother, he would not obtrude his views at present, although he was a critic prepared to defend his pet theory. He would repeat that he set great store by Mr. Lomax's paper, and as a means of correlating seams, very possibly of turning a newly-discovered seam to the best account, of indicating the proper precautions against explosions, and of suggesting the best means of eliminating a maximum of the ash, he could imagine Mr. Lomax's line of investigation proving of the greatest value, but on the origin of coal there was some danger of its proving too much. They were all agreed that the remains of plants abounded in and around coal-seams, and certainly the further details given were most interesting; but what he could not subscribe to—at present, at least—was the exclusively vegetable origin of coal. The paper showed that the best observers had made mistakes in the identification of minute objects seen by the microscope, so that he thought it necessary to advise a cautious attitude as not unbecoming. It would be presumptuous to say more in this connexion; but, granting that Mr. Lomax was correct with regard to the spores and resin (although the latter

seemed excessive in some of the sections, and was suggestive of turpentine as a bye-product in modern coke-ovens), there were still the humus and charcoal, and the greater part of the "sapropelic" coal, to be accounted for, which had not been proved to be vegetable matter. Then there was the great difficulty of sulphur, which occurred in practically all coals, and in many to a very notable degree; sulphur was not a vegetable product, so far as he was aware.

Turning to the remarkable instance described of a lycopod which must have attained a height of about 150 feet, this plant must have lived throughout the whole period during which the Arley Mine was being formed, and have been in full vigour at the end. Did this not seem a long lifetime under adverse circumstances, if the seam was entirely composed of vegetable matter, principally, indeed, sheddings of the lycopod itself, rotting around it? Again, did not the perfect preservation in which the cones and spores were found argue that they were comparatively quickly covered up, and so protected from atmospheric agencies? Mr. Lomax had stated that there were scarcely any two mines which had the same ornamentation on the outer edge of the spores. He (Mr. Burns) was not clear whether by two mines Mr. Lomax meant two different seams in the same locality, or the same seam in two different pits. If the former, there was great prospect of being able to correlate seams by microscopic examination; if the latter, very little. But was not this same evidence in favour of his (Mr. Burns') segregation hypothesis, rather than of Mr. Lomax's organic one, as one could more easily imagine the conditions varying a little from point to point after the matter had been covered up, than the climatic conditions altering while the trees were growing?

DISCUSSION OF MESSRS. H. F. BULMAN AND W. B. WILSON'S PAPER ON "MINERS' BATHS."*

Mr. MARK FORD (Washington) said that he thought it would be very useful if the sanitary aspect of the question was discussed. There was no doubt that the North of England custom of shifts, and of the men bathing at home, was conducive to good health; and in the paper no mention was made as to the health of the

* *Trans. Inst. M. E.*, 1912, vol. xliii., page 92.

miners, whether it was better in Belgium and Germany or otherwise. Thirty years ago, at Washington Colliery, they had two fore-overmen, two back-overmen, and two master-shifters. One fore-overman was over 70 years of age when he died, while the other became under-manager, and died when 75 years of age. One back-overman retired when 75 years of age, and died when 78 years of age; the other was promoted, when a very old man, to be master-wasteman, and died when 75 years of age, being at the pit every day until his death. The two master-shifters both lived until they were over 70 years of age. There was also a master-wasteman who retired when 75 years of age, and who died when 82 years of age. This had always appealed to him as indicating that mining was a very healthy occupation, and it was testified by statistics that the miner, despite his probable early despatch, laboured under conditions which were conducive to longevity; and he (Mr. Ford) had sometimes thought that the foreshift, and bathing at home with hot water, had a good deal to do with it. It needed hot water in a bath to get the dirt off a man's body, and he thought that going immediately into the outside atmosphere after bathing, and walking home with an empty stomach, could not be conducive to the health of the miner.

He thought Mr. Merivale's argument, that it would be better for colliery-owners to provide baths at the pit rather than in the miners' houses, was very weak. He believed that experts would push the question of having baths in the houses, and perhaps properly so, because, while there was only one person in a family who would bathe at the pit, there would be four at home who needed just as much bathing, probably more, because a miner got his skin washed every day.

Mr. W. B. Wilson (Newcastle-upon-Tyne) said that there was no doubt that the miner's occupation was a healthy one. The longevity instanced by Mr. Ford was attained despite the fact that the men went home damp before their bath; it was probable that even a greater age might have been attained if they had taken their bath at the pit before they went home.

At the time when the paper was written, it appeared highly probable that the adoption of pit-head baths was to become compulsory in this country; and, before going to the Continent to examine the different installations there, the writers had taken

some trouble to ascertain where the best installations were to be seen; they therefore considered that the places described might be accepted as being fairly representative. The writers were fully aware, as mentioned by Prof. Louis, that open plunge-baths were very general at the coal-mines in Westphalia 10 or less years ago; but those baths for several and obvious reasons appeared to have been entirely superseded by the overhead spray-bath, which was both sanitary and, so far as the consumption of water was concerned, economical. This type was certainly now general in the three Continental coal-producing countries. Prof. Louis spoke of seats being placed under the sprays, but at none of the several collieries visited were such provided; moreover, the writers considered that they would be quite unnecessary, and would defeat one of the main objects of the system, which was expedition—a man would wash himself much more quickly in an erect than in a sitting position. As mentioned in the paper, foot-rests were occasionally provided. At some of the collieries visited padlocks for securing the bundles of clothes while they were suspended in the drying halls were in general use; at others, although provided for, they were only used by a few of the workmen; whilst at others, again, no provision appeared to have been made for such locks. It was compulsory under the Metalliferous Mines Regulation Acts, where more than twelve persons were employed below ground, to provide sufficient accommodation above ground, near the principal entrance to the mine, to enable those employed to dry and change their clothes; but these places were rather primitive, compared with the extensive and orderly arrangements found on the Continent. It was often urged that it would be dangerous or harmful for workmen to walk home after coming straight from a warm bath, but the writers agreed with Mr. J. H. Merivale that bathing and changing clothes on coming out of the pit, rather than after they had returned home, would save miners from many of the bronchial and other troubles to which they were liable. Surely it would be less harmful, and much more comfortable, to walk home with perfectly dry and warm clothes, than to go home and hang about in damp and dirty clothes. Moreover, what did the miner do at present? The foreshift man might go to bed after his bath in the middle of the day, but the backshift hewer, and other day workmen, would invariably walk out immediately after his warm bath at home. At most of the bathing establishments waiting-

rooms were provided, where men might remain until they felt cool. Another provision tending to promote the health and comfort of the workmen was a covered-in bar, where they could obtain, at cheap rates, light refreshments, such as hot milk and cocoa. This was placed within the colliery gates, as at Rhein-Preussen, where the men passed it on coming out from the bathing-hall. At some Belgian collieries, too, canteens were provided near the bath-houses, supplying hot coffee.

The question of first-cost was the serious difficulty, especially when so many other charges were being forced upon the owners of collieries; but, as had been very pertinently pointed out by Mr. Merivale, the popular and growing feeling in favour of improved housing might, before long, compel owners to provide baths in some form for their workmen, in which case such installations as those described in the paper might be adopted even for reasons of economy.

Mr. C. H. Merivale had spoken of the desirability of privacy while bathing. The different customs in this respect were fully described in the paper.

The question of cost of maintenance had been raised, and it might be useful to quote information on that point, given by H.M. Chief Inspector of Mines.* At Wharncliffe Silkstone Colliery there had been baths on a small scale for a number of years, Mr. G. Blake Walker stating the first-cost as about £500, and the cost of upkeep, including attendance, heating, lighting, and depreciation, as about 30s. per week. The baths were fairly regularly used by forty-eight men, each man contributing 2s. per quarter, and providing his own soap and towels. Thus the contribution of each man towards the upkeep of the baths amounted to 1·85d. per week. The yearly cost to the company, after deducting the £19 contributed by the forty-eight men, would be £59, or nearly 12 per cent. on the first-cost.

According to information supplied by Mr. Victor Watteyne, Chief Inspector of Mines, Brussels, at thirteen collieries in Belgium, employing 9,570 men, the first-cost of the bathing establishments amounted to £20,092, or an average of about £2 2s. per man employed. Of the total number employed, 6,640 men, or 69 per cent., used the baths. The cost of maintenance, heating,

* *Mines and Quarries: General Report, with Statistics, for 1910, Part II.—Labour*, by The Chief Inspector of Mines, 1911 [Cd. 5940].

lighting, and attendance, was given for twelve of these establishments, the average being close upon £14 per month, or £168 per year. Divided over the men using the baths, it averaged 7d. per man per month, or 7s. per year. The yearly cost of maintenance, which apparently did not include depreciation, worked out at about 11 per cent. of the first-cost. The cost per bath, including soap, brushes, and the salaries of attendants, averaged 0·375d., and that figure was corroborated in an article on "Miners' Baths," which appeared in *The Iron and Coal Trades Review*.* Statistics of the cost of nine bath and dressing-room installations in Belgian mines and fuel-works were tabulated, as supplied by Mr. Richard Jacobson, London, and it was stated that the cost per bath ranged from 0·25d. to slightly over 0·50d.; but this amount did not include capital-cost. The same article contained a description of what was probably the most complete and important bathing installation yet erected in Great Britain, that at the Winnington works of Messrs. Brunner, Mond, & Company, Limited.

Separate figures were given for the coal-field of Liége, the capital-cost of erecting the baths varying from £2 to £3 10s. per head. Taking a cost-price of £2 8s. per workman, and a rate of 15 per cent. for interest, redemption of capital, and depreciation, and taking 300 working days in the year, the capital-cost worked out at 0·3d. per bath.

In Westphalia, it was stated that the first-cost was about £4,000 for every 1,000 workmen, that the yearly consumption of water was about 1,980 gallons (9 cubic metres) per man, that the steam required for heating the baths and building was about 1 ton per man per year, and that the cost amounted to about 2¼d. per man per week, inclusive.

With regard to the quality of the water, at very few collieries would there be a choice of supply, and the available water would consequently have to be used. Doubtless the consumption of water would increase with the degree of hardness, and the water supplied to the East Durham district, by the Sunderland and South Shields Water Company, was intensely hard; but, in any case, the cost of water would not be heavy. If 10 gallons per bath were allowed, which was a liberal amount, and the water cost 10d. per 1,000 gallons, the cost per bath would only be 0·1d.

* 1911, vol. lxxxiii., page 886.

At some foreign establishments where there was a difficulty about water, it was the practice to purify the water coming from the baths, and to use it over again.

The PRESIDENT (Mr. M. W. Parrington) said that when several thousand persons used the baths, the cost mounted up. Taking water at 8d. per 1,000 gallons, and allowing 10 gallons per bath, for a large colliery with 2,000 men to bathe every day, supposing that they all bathed, it would cost £200 a year for water alone. Mr. Wilson, he thought, had understated the cost of maintenance, and had also now given lower figures for capital outlay than had been tabulated in the paper, in which £4 to £4 16s. per head was stated.

Mr. WILSON said that the cost of maintenance largely depended on the number of men. The writers had taken the price of water at 10d. per 1,000 gallons, thinking that 10d. was not an unusual figure, and, allowing 10 gallons per bath, it was easy for purposes of calculation. The figures given in the paper were actual ones. In Westphalia, for 1,000 men the capital outlay necessary was stated to be £4,000, which was £4 per man.

The PRESIDENT remarked that the Germans were proverbially economical in laying out anything of that sort, and, so far as he was concerned, he thought it safe to take the capital outlay at £5 per head; with 2,000 men bathing every day, the initial outlay was £10,000. He was bound to say that he agreed with Mr. Ford as to the danger, speaking from personal experience, of going out immediately after a hot bath. He never dared do it when he was going down the pit regularly. At the same time, he agreed that many men would go home and have a hot bath and then go out immediately, but that was from their own choice. They were bound to turn out of the bath at the colliery as soon as they were washed.

Mr. WILSON said that this was not necessary; they frequently had ante-rooms in which to remain, if they thought fit to do so.

The PRESIDENT said that this question came in: if they turned the miner out as soon as he had had his hot bath, and he caught pneumonia and died, would it be considered as an accident, as he had got it in the ordinary course of his employment?

THE MANCHESTER GEOLOGICAL AND MINING SOCIETY.

GENERAL MEETING,
HELD IN THE ROOMS OF THE SOCIETY, QUEEN'S CHAMBERS,
5, JOHN DALTON STREET, MANCHESTER,
APRIL 9TH, 1912.

MR. GEORGE B. HARRISON, PRESIDENT, IN THE CHAIR.

The following new members were elected, having been previously nominated:—

MEMBERS—

Mr. HUGH BROCKLEHURST PILKINGTON, Mining Engineer, Clifton & Kersley Coal Company, Limited, Manchester.

Mr. STEPHEN RATCLIFFE ELLIS, Mining Engineer, 33A, King Street, Wigan.

ASSOCIATE MEMBER—

Mr. ALFRED ROBIN MARTYN LEES, B.Sc., The Moor House, Congleton, Cheshire.

STUDENTS—

Mr. ROLAND RATCLIFFE ELLIS, Mining Student, Wigan Coal & Iron Company, Limited, Wigan.

Mr. CEDRIC CALVERLEY HOGG, Mine Surveyor, Norley Colliery, Pemberton, Wigan.

DISCUSSION OF DR. JOHN HARGER'S PAPER ON "THE PREVENTION OF EXPLOSIONS IN MINES."*

The PRESIDENT (Mr. George B. Harrison) said that most of the members present would have some knowledge of the subject of Dr. Harger's paper; and, owing to the importance of the subject, the ability of the writer of the paper, and the unusual method proposed therein, it had received considerable notice. Apart from accepting the method advocated in the paper, he considered Dr. Harger's paper a very valuable contribution, and he had read it again with interest. With regard to the statement that "large dust explosions were a modern production, and may be said to date from and be caused by the Coal Mines Regulation

* *Trans. Inst. M. E.*, 1912, vol. xliii., page 132.

Act of 1872 and subsequent laws," he thought that it could be demonstrated that but for the great improvement in the ventilation of mines the loss of life by explosion since 1872, deplorable as it had been, would have been greater still. A casual reader of the paper, not knowing the facts, might form the impression (although he did not think that such was intended) that although the number of explosions had been reduced, the disasters were so great when they did occur that no improvement had taken place. What were the actual facts? Mr. John Gerrard, in his Presidential Address before the Society in 1904,* traced the steady improvement in the reduction of loss of life from accidents of all kinds from 1850 to the end of 1903, and he rightly stated that "the most striking feature in these tables was the large reduction of loss of life from explosions."

In the tables for the 5 years 1851-1855 the deaths from explosions of fire-damp and coal-dust were 1 per thousand persons employed above and below ground. If he (Mr. Harrison) were dealing with the subject, he would only deal with persons below ground; but these figures were tabulated to include all accidents, both below and above ground. The proportion of people employed above ground in modern times was greater than in those earlier years, and therefore it did not take away from the argument. The proportion of deaths in those 5 years was 1 per thousand employed above and below ground, or 3·967 per million tons of coal raised. In the 5 years 1870-1874 it was 0·4 per thousand persons, or 1·371 per million tons of coal raised. For the 5 years 1899-1903, the last period taken by Mr. Gerrard, the figures were 0·075 per thousand persons, or 0·253 per million tons of mineral raised. For the last 5 years, 1907-1911, the loss of life by explosions, per thousand persons employed above and below ground, was 0·185, and per million tons of mineral raised, 0·668, an increase as compared with previous years, owing to the three explosions at Maypole, Whitehaven, and Hulton Bank Collieries, but still less than half the loss in the 5 years 1870-1874, and less than a fifth of the loss of life by explosions in the early fifties.

With regard to the quotation of a witness's evidence as to mines being much dustier in 1834 than now, he thought that few

* *Trans. Inst. M. E.*, 1904, vol. xxviii., page 360.

mining men could support that statement. His own experience did not go back before the early seventies, but he was of opinion that mines had become dustier as they got deeper and further in, with increased output. Even where pits were dusty in his younger days, the haulage, at least in-bye, was by horses, and the dust raised by their feet was not nearly so dangerous as now, when the haulage was all mechanical. Dust, he believed, had played a large part in many explosions which in former years were solely attributed to fire-damp.

With regard to the three serious explosions in the Lancashire district during Mr. Gerrard's inspectorship, those at Shakerley and Stoneclough were solely fire-damp, and originated at or near the face beyond a doubt. He thought that few mining men would agree that, generally speaking, the ventilation on the faces was at all excessive, and those who knew the trouble involved in keeping places clear, and the number of times that the official had to fence places off, were aware how often it proved insufficient. However, he personally welcomed Dr. Harger's contribution towards the solution of the problem of explosions in mines, and would be glad to see either his or some other method prove efficient and simple in application.

Mr. Joseph Dickinson (Manchester) said that Dr. Harger's proposal might have some merit, but it was certainly not in accordance with what had been aimed at during recent years—at all events, since 1850. It had had wide publicity, had been noticed largely by the press, and had been the subject of a question in Parliament. But the theory was not so new as many people seemed to suppose. Something similar had been practised at downcast shafts, and there had been among the numerous papers read before this Society a proposal that high-pressure steam should be sent in with the intake air, but none of these proposals was brought into practical operation.

Under the modern system of ventilation certain signs of danger on the miners' lamps, such as the long blue cap—blue, with a tinge of brown in it—had certainly disappeared, owing to the increase of air. There certainly had been more violent and more extended explosions of recent years, but whether the remedy was to be found by sending in an impure air to contend with the fire-damp and the black-damp, he could not say: it seemed to him to be going backward. The idea was to rely

chiefly on adequate ventilation, and he thought that it would take some time to persuade miners now that improvement was to be effected by sending in impure air.

Sir HENRY HALL (Chester) said that he regarded Dr. Harger's suggestion as rather a startling proposal. It upset their ideas entirely of what the ventilation of a mine ought to be. It also opposed the popular idea that the fresher the air was, and the more oxygen it contained, the better for the individual. Dr. Harger brought before them the fact which he (Sir Henry Hall) thought they all admitted, that the more ventilation there was, if there did happen to be an explosion there would be a more violent one than if there had been less ventilation. Dr. Harger went on to argue from that, which was quite natural, that if one proceeded in the reverse direction far enough, one would come to a time when there could be no explosion, and he told them that circumstance arose when the normal percentage of oxygen was reduced to 17½ or 18 per cent. and ½ or 1 per cent. of carbon dioxide was added to the atmosphere. Dr. Harger instanced the fact that the atmosphere high up on a mountain contained less oxygen than it did at the sea-level, and that people were still able to live and work at those high altitudes just the same as they could in lower places. He was told the other day—this might be interesting to Dr. Harger—that flying men who were in the habit of flying at high altitudes, although they did not feel anything special at the time, suffered from illness later on, and several had been compelled to give up flying for that reason. He himself was not sufficiently a chemist to know what the effect would be on men living in an atmosphere such as that in which Dr. Harger proposed that they should live and work.

If Dr. Haldane had expressed any opinion on this paper, he would like to hear what was that opinion. The idea of working in an atmosphere to which certain (not very pleasant) gases had been added, and from which a certain amount of oxygen had been taken out, did not appeal to him. His experience down the mines had always been that at the far ends, where there was very little air, one felt partially overcome, and the instant one passed from such a district to a place where there was better ventilation one felt refreshed at once. Whether that might be due to the additional quantity of the oxygen in the fresh airways or not, he

could not say; but there was the fact that a person might be thoroughly exhausted, almost overcome, and as soon as he got into a fresh airway he recovered straight away.

There was this rather interesting remark on page 133 of the paper:—"No one would know that he was breathing anything different or unusual if a supply of 17½ per cent. of oxygen with 82½ per cent. of nitrogen were put into a room to replace the ordinary air." That might be so, but perhaps Dr. Harger would tell them whether, if to that atmosphere was added some of the flue-gases that he proposed to put into the pit atmosphere, the person entering the room would not at once recognize the fumes? He (Sir Henry) agreed entirely with the statement on page 138 that "There has been a great deal written and talked about the dust, but curiously enough the oxygen, which is at least equally important, has been left almost entirely out of the question." Dr. Harger had said that to have an explosion there must be two factors—dust, and oxygen to burn it, and, if either one or the other could be got rid of, there would be no ignition. That was quite apparent, and it might probably prove much easier to get rid of a part of the oxygen in the atmosphere than to get rid of the dust from the mines. It was a fact, he thought (and Mr. Dickinson had just referred to it), that where there was impure air in a mine, and if an ignition of gas took place, the explosion would be less violent than with fresher air, and Dr. Harger had used that fact as an argument to prove his case. But he (Sir Henry) was in this difficulty: in those parts of mines where the air-current was feeble and impure the lights still continued to burn, whereas in Dr. Harger's atmosphere ordinary lights would not burn. If the lights would burn, then he did not see how Dr. Harger could make out, or at any rate prove, that there could be no ignition of gas, if it happened to be present.

On page 142 there was an interesting statement. It was, if he understood what was meant, to the effect that if one tried to light a mixture of air and gas, or air and coal-dust, by an electric spark, the desired object was much more likely to be attained by that means than if with a candle or any other kind of open light, and he thought that fact went to explain why, in many of the recent experiments that had been carried out by eminent mining engineers, ignitions of dust were so readily

obtained. When the mixture was ignited by an electric spark, the experiment succeeded almost every time. Dr. Harger had pointed out that in one case, at any rate, an electric spark exploded a mixture of fire-damp and air at once, after he had failed to get it to explode by means of an ordinary light.

Dr. Harger had referred to some of his (Sir Henry Hall's) remarks, or rather conclusions, set forth in a report which he had made a long time ago, to the effect that the dust from certain coal-seams was not explosive. He (Sir Henry) had really come to the conclusion that nearly every dust that he had tried was explosive to a certain extent. The only decided exception seemed to be anthracite from South Wales; and Dr. Harger appeared to be of the same opinion with regard to anthracite.

With reference to that particular matter, in his report made about 20 years ago,* he had made the following statement:—

"It is true there were exceptions to this rule, as in the case of the samples received from the Forest of Dean, Somerset, South Stafford (Great Fenton and West Cannock), Lancashire (Moston), and South Wales anthracite. The difference in the results from these dusts was, I think, due to some difference in the character of the coal-seams in those districts. There were also partial failures with the samples from Auckland Park and Trimdon Grange (Durham), and from Talk-o'th' Hill, Astley and Tyldesley, and Llanerch, but in these latter cases I am satisfied that a little more perseverance with the tests and a more careful collection of the samples would have resulted in explosions."

The fact was that the dust with which he was experimenting came chiefly from the floor and roof, which at that time was considered to be the most dangerous, but was afterwards proved by analysis to contain a large percentage of ash. That left them in a position, which he thought was correct, namely, that dust recently made and recently deposited was the most dangerous. At present he was of opinion that almost every dust could be exploded if there was sufficient air, except, perhaps, anthracite. The anthracite with which he experimented came from Gwaun-cae-Gurwen, Glamorganshire. This dust was fine and black, and was collected from a crusher on the surface. There were no actual explosions, but the electric firing wires were charred for 30 or 45 feet up the pit.

He thought that the explanation of the fact mentioned by

* *Report to the Royal Commissioners on Explosions from Coal-dust in Mines*, by Henry Hall, Esq., one of H.M. Inspectors of Mines, dated 20th August, 1893, page 15.

Dr. Harger, that he did not get ignitions in all his experiments, was due to the amount of inert matter in the samples, as there would be ash in the samples experimented with. He had himself found that with dust from Lightmoor Colliery (Forest of Dean), which contained a large quantity of ash—46·8 per cent.—there was no explosion at all in his experiments. On the other hand, the dust from a Scottish colliery exploded violently, although analysis showed a large percentage of ash.* In his opinion, the dusts that caused the most violent explosions were those which came from seams that had a high percentage of volatile matter. That, however, was contradicted to some extent by the successful experiments with dust from Albion Colliery, Glamorganshire, which does not contain a high percentage of volatile matter.†

Dr. Harger was rather severe in his remarks with reference to the Government and the mining inspectors; he seemed to hold the Government and the inspectors responsible for the mines being ventilated with such large quantities of air as was the case at the present day. The Government and the inspectors only acted on the best advice and experience of the leading mining engineers, so that they must all share the blame, if there was any, for sending larger quantities of air into the mines.

The last paragraph of the paper, he thought, contained a valuable suggestion. It was clear that they might, with very great advantage, use this process when there were fires underground. These fires often had to be drowned out by water, to the serious damage of the workings, whereas fumes could be applied at a trifling expense and with a great saving in time.

In conclusion, he thought that the suggestion of Dr. Harger was very well worth persevering with. He considered that the subject should be fully and fairly tested, and that possibly the Government testing-station at Woolwich might be used with advantage. Of course, the first thing to be assured of was that men could live and work in an atmosphere such as that suggested.

Mr. Joseph Dickinson said that the late Mr. Thomas E. Forster, who was considered to be a very practical colliery viewer, had stated that with increase of air there would be an

* *Op. cit.*, pages 13 and 15. † *Ibid.*, page 11.

increase in the destructiveness of the explosion, and that had been the case, although of late years explosions had diminished very much in number. Could Sir Henry Hall tell them how much the detonation of air in the mine contributed to the explosion?

Sir HENRY HALL said that there was no explosion—neither by detonation nor anything else—when there was no dust there.

Dr. J. S. HALDANE (Oxford) wrote that Dr. Harger's paper was a very interesting one, and raised so many points for discussion that he could only refer to two or three of them.

In the first place, he did not think that there could be any doubt that a mere reduction of the oxygen percentage to, say, 17½, would not noticeably affect the working powers of the men. The air in the mine with 17½ per cent. of oxygen would be similar in its action to that of a town at about 5,000 feet above sea-level, say, Denver; and persons going to Denver experienced no diminution in their working powers. The well-known physiological effects of mine air, reduced to 17½ per cent. by admixture with black-damp, so that a candle would be just extinguished, were certainly due entirely to the carbon dioxide, of which 2 to 3 per cent. would probably be present. If any carbon dioxide were added to the air, the quantity would have to be very small, as the presence of anything over 1 per cent. would begin to hamper men appreciably in their work, although it would not be noticeable during rest.

Furnace-gas, if used for reducing the oxygen, would require very thorough purification from smoke, suspended sulphuric acid, and gaseous sulphurous acid, as well as from most of the carbon dioxide; and the carbon monoxide would need to be consumed by some absolutely certain process which could never fail. The conditions which existed on the Metropolitan Railway, before electric traction was introduced, furnished some guide as to what would happen if furnace-gas not freed from carbon monoxide were introduced into a mine. He (Dr. Haldane) had investigated the tunnel air on behalf of a Committee of the Board of Trade, which reported on the subject and advised the introduction of electric traction.* The engines used

* *Report of the Departmental Committee on Metropolitan Tunnel Ventilation*, Parliamentary Paper [C8684], 1897, Appendix I.

smokeless coal, with a low percentage of sulphur. If furnace-gas of similar composition to that given by the engines, but freed only from carbon dioxide and suspended impurities, were employed, about 0·24 per cent. of carbon monoxide would be present when the oxygen was reduced to 17·5 per cent. With the reduced oxygen percentage this would have the same effect as 0·32 per cent., and would be sufficient to kill every man in a pit. Dr. Harger had referred to the danger from carbon monoxide, but did not say how he proposed to deal with it, or what the total cost of purification would amount to. As much as 0·01 per cent. of carbon monoxide in the air of the mine would be an absolute bar to the use of flue-gas.

The effect of a reduction in the oxygen percentage on the ignitability of coal-dust, as stated by Dr. Harger, seemed to be quite clear, and was what might be expected from the known effects of a reduced oxygen percentage on flames generally. It seemed very doubtful, however, whether the reduced oxygen would have an equal effect in preventing the propagation by coal-dust of an explosion started otherwise, if once an increased pressure had been developed. Increased atmospheric pressure favoured combustion.

With regard to the effects of a diminished oxygen percentage on the explosibility of fire-damp, Dr Harger's experiments seemed to be at variance with the results which Dr. W. N. Atkinson and he (Dr. Haldane) had obtained.* They had found that methane, when mixed with black-damp and air, formed explosive mixtures even when the oxygen was reduced to as low as 12 per cent., and they had laid great stress on the dangerous mistake of assuming that because a mixture of black-damp and fire-damp would put out a light at a certain dilution with air, it could not form an explosive mixture when less diluted with air. This mistake had probably cost many lives, and it rather looked as if Dr. Harger had fallen into it. His and Dr. Atkinson's experiments were made with natural methane and black-damp, and the mixtures were ignited with an ordinary candle-flame. If their results were correct, as they had hitherto believed them to be, they showed that a reduction of the oxygen to 17½ per cent. would be a very poor protection against gas explosions. There

* See *Trans. Inst. M.E.*, 1895, vol. viii., page 549.

was also no reason for supposing that such a reduction would do much towards combating gob-fires, except to prevent them from producing actual flame. The oxidation on which the heating depended would still go on, so far as was known, although at a slightly reduced rate, corresponding to the slightly reduced percentage of oxygen in the air.* It seemed to take extremely little oxygen to keep a gob-fire going. On the other hand, the risk of ordinary accidental fires on roadways could be reduced to *nil* by reducing the oxygen percentage, and this would be a solid gain.

It seemed to him (Dr. Haldane) that Dr. Harger had overestimated the influence of reduced oxygen, and had failed to take account of other more important factors, such as the absence of fine coal-dust and the presence of stone-dust, in protecting the working-faces and returns from dust explosions in many cases.

It must be evident that the necessary experimental data did not yet exist for coming even to a provisional conclusion as to whether Dr. Harger's proposal could be turned to practical account, but there could be no doubt that he had directed attention to factors which had hitherto been overlooked, and to possibilities which might come to be of great practical importance.

Dr. HARGER (Liverpool University), in his reply, said that the President had stated that the reduction in the loss of life from explosions in the course of 50 years was from 1 per thousand to 0·075 per thousand. It must be remembered that there were a great many factors to be considered besides the mere increase of ventilation. For instance, in the old days, when Mr. Dickinson was an active Inspector of Mines, candle-flames were used. In fact, Mr. Dickinson was mainly instrumental in doing away with those open lights in the mines of Lancashire. He thought that explained the reduction in the loss of life from explosions. A few years ago they had safety-lamps which were, in fact, not safety-lamps, but really worse than none at all, for men used them when they would not have done

* See in this respect "Observations on the Relation of Underground Temperatures and Spontaneous Fires in the Coal to Oxidation and to the Causes which favour it," by John S. Haldane and F. G. Meacham, *Trans. Inst. M. E.*, 1898, vol. xvi., page 457.

so had they not thought the lamps safe. Only in recent times had they got a real safety-lamp—he presumed that the lamps were now safe. At the same time, the figures as regarded loss of life had gone up recently, on account of those huge disasters in 1909; and Great Britain had not been treated worse than any other country. In the year when the Courrières disaster took place, the number was brought up to 7 per thousand in France. In the United States of America, dust explosions still continued to occur at frequent intervals; and he thought that the decrease in the number of deaths was not due to the increased ventilation, but to the enormous number of safeguards now taken to prevent ignition of the dust—including the watering of the dust where an explosive had to be used. A great number of regulations had to be taken into consideration in dealing with the causes of the reductions mentioned by the President. Many of these regulations were not known at the time when the rate was 1 death per thousand. The explosions nowadays were more disastrous than they used to be, and that, he submitted, was due to the excessive ventilation.

In the old days if an explosion had occurred at Hulton Colliery, only a few men would have been burnt near where the ignition took place. Hulton Colliery was probably one of the most excessively ventilated collieries in the kingdom.

He had been during the past week in the South Yorkshire district, looking at gob-fires (about half a dozen of them), and was much astonished at the great differences in the management of them. Some managers knew that they were doing wrong if they sent a quantity of air into the mine. If an Inspector complained of the small amount, the manager would tell him to come and manage the pit himself. In other mines the ventilation was excessive, and the consequence was more gob-fires. The principal factor in originating a gob-fire was excessive ventilation. In the South Yorkshire coal-field excessive ventilation was extremely dangerous, and the deeper they went down into dry hot mines, the greater was the liability to gob-fires so long as excessive ventilation prevailed. Only those who had had experience of such fires knew what terrible affairs they were.

With regard to some of the remarks made by Mr. Dickinson, that the greater the ventilation was the more disastrous were

the results when an explosion occurred, it was well known that such was the case. The old blue books were full of such cases. As a matter of fact, it was this coal-dust evidence gathered in the years 1901 to 1904 that first put him (the speaker) on the track of tracing the coal-dust explosions back to excessive ventilation. At that time a great many people did not believe that dust mixed with air gave an explosion.

With reference to Sir Henry Hall's question about flying men going high and suffering illness afterwards, he was not a medical man and did not quite know to what that would be due. Of course, it was known that if a man went up suddenly to a very great height, he was apt to become ill; if taken up too suddenly, he would die; but in the present case there would not be sufficient difference in the air to make illness possible. He should say that, as a matter of fact, the illness of a flying man was due to causes affecting the nervous system. We knew that flying men had to give up flying after a year or two because their nerves became absolutely shattered.

With regard to the relief experienced by a man coming from a confined place into the intake air, he submitted that the effect was due to the change from a warm moist atmosphere into a cool dry one. That immediately braced one up. It was the moisture in the return ways as much as anything that had a depressing effect.

Sir Henry Hall had also said that he did not understand the statement that an atmosphere containing 14 per cent. of oxygen at sea-level corresponded to a much smaller percentage in a mine 3,000 feet deep. In the case of combustion it was the percentage of oxygen that mattered; but, in the case of respiration, it was the actual quantity, the weight of oxygen in a given volume, that counted.

There was one thing that Sir Henry did not bring out, which, having studied Sir Henry's experiments, always struck him as rather remarkable. In one shaft Sir Henry had a small coke-fire lighted to produce a current of air from one shaft to another, and it was very remarkable that in not one single experiment in that series did he get an ignition. Now it had always struck him (Dr. Harger) that the reason why he did not was that part of the oxygen had been removed from the air by the coke-fire, and a little carbon dioxide put in the air, too. He had always taken

that as a great point as bearing out the facts that he had found —that a small reduction of oxygen and the addition of a little carbon dioxide would prevent a dust explosion.

Sir HENRY HALL questioned whether his having experimented with a coke-fire was recorded;* but he could say that when these experiments were first tried, an old shaft with no ventilation was used, and they only got about one explosion in nine or ten trials Later they put up a small fan with air-pipes, and then they got an explosion almost every time. That accorded very much with Dr. Harger's view—the more the ventilation the greater the danger.

Dr. HARGER, continuing, thought that there was a difference between an open light and an electric spark in starting an ignition. In certain experiments he was obliged to use electric sparks, because other lights would not start the explosion. His purpose in the experiment was to show that with one kind of air an explosion was obtained, but with another no explosion occurred. It was immaterial what kind of light was applied.

Sir HENRY HALL suggested that with an electric short-circuit an explosion might be got in an atmosphere that would not cause one if the lamp were opened in it—an atmosphere that was not actually explosive as one understood it. That added still another danger to the known dangers of electricity.

Dr. HARGER said that was undoubtedly so. With regard to the amount of ash in the dust, it would be seen that in part of his paper he explained why one dust would ignite and another would not. It was owing to the amount of ash in the coal-dust. In some cases he had got an explosion with 24 per cent. of ash in the dust. Taking the case of the Hulton explosion, it started in the Plodder Mine and went through the Yard and the Three-Quarters. If the dusts of those mines were examined, they would be found to ignite. The explosion spread to the Arley Mine,

* Sir Henry Hall afterwards wrote that, on referring to an official report made by him to the Secretary of State in 1890 [Cd. 6543, page 152], he found that Dr. Harger was quite right when he stated that in one series of experiments a coke-fire was used, and that in no single instance in that series was there an ignition of dust.

travelled for about 60 feet in it, and then stopped. If the dust in the Arley Mine were examined, it would be found to be one that would not ignite under conditions similar to those applied to other dusts. It was therefore proved that it was a kind of stone-dust that prevented the explosion from spreading, or the death-roll would have been increased by another 300. As a matter of fact, the Arley Coal, when pure, was much more inflammable than any other in that mine. Generally speaking, the more volatile matter there was the more inflammable was the dust.

He (Dr. Harger) thought that the letter from Dr. Haldane was very interesting, especially that referring to tunnel ventilation. He had had a good deal of correspondence with Dr. Haldane, and the latter was of opinion that, provided that all the impurities could be removed from flue-gas, with the exception of the nitrogen, and a little carbon dioxide, there was not the slightest objection to its use. He (Dr. Harger), as a practical chemist, had no difficulty whatever in taking flue-gas and removing all the impurities. No one wanted to send down the mine anything that was not perfectly safe.

It was, of course, a matter for the mining engineer and the chemical engineer. He did not think that a chemist, with only University training, was of any use in dealing with technical problems; and personally he thought, and it was well recognized, that a University man's opinion on a technical process was not worth anything. He submitted, therefore, that flue-gas could be purified effectually and at no great cost.

Another very important point in the letter was that about the ignition of fire-damp. Dr. Haldane had stated that he had used "natural methane." It was very much more satisfactory than making it in the laboratory, but still he did not think that it was pure methane. One could generally smell gas in a mine, but not if it were pure methane. If there was plenty of gas in the air, it could be smelt. There was no need to look for a cap. Pure methane was not easily ignited. A red-hot poker would not ignite it, but an electric spark would. He thought—in spite of all the work that had been done—and there had been a good deal—that there was plenty of work still to be done in connexion with fire-damp, for he believed that the symptoms one got from a bad atmosphere had nothing to do with methane,

but were due to some small trace of poisonous gas. In the best ventilated mines, in the main return airways, there were traces of carbon monoxide. If that were so, then in badly ventilated parts the quantity might be increased to an amount to give the person breathing it a very bad headache. He did not think that it was due to fire-damp or to black-damp; he believed that it was due to the presence of small traces of carbon monoxide or other poisonous gases. In conclusion, he (Dr. Harger) reaffirmed his belief as to the practicability of men living and working in the mines in the atmosphere indicated in his paper. Such an atmosphere, he was convinced, would in all mines be sufficient to stop a dust-explosion.

With regard to the point raised by the President at the former meeting—concerning men fleeing from outbursts of fire-damp—he submitted that the conditions which he proposed would be greatly to the advantage of the men, because they could use a light which would last as long as they themselves lasted: there would not be the danger of their lamps going out if they ran, as there would be under existing conditions. Supposing the air to contain 21 per cent. of oxygen, when the percentage was lowered to 19, the men began to run. It was a race between the gas and the men. Their margin of safety was 2 per cent. If they ran, they would lose their light without doubt, if it were a safety-lamp burning oil; then they would have to go slowly lest they should stumble over some obstacle, or lose their way. Now, if this reduced quantity of oxygen were introduced, and the men had an acetylene-lamp instead of the ordinary oil-lamp, they would find that their light would burn until the percentage of oxygen was reduced to 12. The men, therefore, with such a lamp had a bigger margin of safety. If the men had an acetylene-lamp and 19 per cent. of oxygen, they could go on until the percentage of oxygen in the air was reduced to 12 before their light went out. They would probably lose their light at that point if they ran, but if they kept still they could go on until a percentage of 9 was reached. There was therefore an enormous advantage in a man being able to keep his pace with a light that would burn if 12 per cent. of oxygen were present, whereas under the present system the lights did not serve if the percentage fell below 19.

Mr. H. STANLEY ATHERTON (Bolton) asked whether acetylene-lamps were not apt to become very hot.

Dr. HARGER replied that if there was a reduced quantity of oxygen, the lamp would not give out so much heat. It had always puzzled him why such lamps had not come into more general use.

Mr. H. STANLEY ATHERTON moved that the cordial thanks of the Society be tendered to Dr. Harger. The members ought to be exceedingly grateful to him for the time and the labour expended in trying to solve the problem of the prevention of explosions in coal-mines. They certainly must admire his courage in coming out and facing the criticism which his proposal could not but call forth. He felt certain that any members of the Society who were interested in this subject would be only too happy to assist him in any way in which they possibly could.

The resolution was passed unanimously.

Mr. WILLIAM OLLERENSHAW (Denton Colliery) wrote that the paper deserved the careful consideration of all who were interested in coal-mining, as there was a possibility that benefits might result from the suggestions made therein. Dr. Harger's recommendations really amounted to this—that the methods of ventilation in use by their forefathers in the early days of coal-mining ought to be reverted to. To do this, it ought not to be necessary to provide the complicated apparatus suggested in the paper, but the object might be attained by reducing the amount of ventilation passing into the mine. There was no doubt that modern methods of mining and ventilation had added very considerably to the liability of greater damage and an increased death-roll from explosions when once started in a coal-mine. If (as Dr. Harger had suggested) the ignition of an explosive mixture of gas or of coal-dust could be prevented, not only coal-miners but the human race would be benefited.

The term "fireman," which was applied to the officials whose duty it was to see to the safety, etc., of the working-places and roadways of mines, was derived from the custom that was prevalent in the early days of coal-mining for the fireman to burn out or ignite small accumulations of gas which were found by

him in making his inspections of the mine. If this duty were attempted by the firemen of to-day, the world would oftener be startled by the report of colliery explosions, owing to the amount of oxygen which was present in the mines as a result of the improved appliances for ventilation which were now in use in nearly every case.

In most mines a fairly large quantity of carbon dioxide was given off naturally from the goaves, wastes, and old workings, probably to a very much greater extent than the half per cent. suggested by Dr. Harger, and it was his (Mr. Ollerenshaw's) opinion that the presence of this gas in the atmosphere in the old days was one of the reasons for their comparative freedom from the evils of extensive and disastrous explosions; yet the presence of carbon dioxide in the atmosphere did not appear to have had any deleterious effect upon the health of the miners (as seemed to be the fear of some of the scientific gentlemen who had contributed to the discussion). As no evidence had been adduced to prove that the health of the miner was affected by the presence of carbon dioxide, it might be assumed that none was available.

If Mr. Harger's paper was the means of experiments being made to establish the truth or otherwise of his claim, the time spent upon the problem would have been well employed.

Prof. W. M. THORNTON (Newcastle-upon-Tyne) wrote that the chief question which seemed to him to arise from Dr. Harger's interesting suggestion was whether, or to what degree, the capacity for sustained physical effort on the part of underground workers would be affected by the reduction of the oxygen percentage when moisture was present. In order to ensure a practical success, there would have to be no consciousness on the part of the workers that the air had been treated. In deep mines there could be little doubt that the reduction of oxygen would give a greater feeling of ease, and the case quoted from Messrs. Cadman and Whalley's report on ventilation showed that there was certainly no discomfort with low oxygen. If it could be shown by actual trial in a mine that the men could not tell when the air was being treated, a great deal of objection to the proposal would vanish.

There was another factor which also could only be determined by large-scale experiments. The reduction of oxygen had been

shown to prevent ignitions of dust by induction-coil discharges, and with a "powerful flaming spark" the oxygen had, in the case of the Barnsley Seam dust, to be reduced to 17½ per cent. to prevent ignition. The energy of the source of a dust explosion in a mine was always greater than a spark. A blown-out shot, the ignition of a pocket of gas, or an electric short-circuit, gave rise to a quantity of heat which was more than sufficient to cause liberation of the volatile constituents of coal-dust in the air, and by their combustion to produce a continued ignition if the dust were present in large enough quantity. As Dr. Harger had pointed out, one possible reason why explosions were not more frequent was that the air might not be rich enough in oxygen to continue the ignition of the gases liberated from dust by a large flash. The distribution of such gas in space was, however, variable and proportional to the density of the dust cloud, and it might be quite possible to have an explosive mixture of gas and air produced by a large flash which would not be produced by a small one. Was the limiting percentage of oxygen required for continued combustion the same at pressures higher than atmospheric? It was necessary to know this, for an explosion-wave once started by whatever means, might possibly proceed by first creating a compression-wave in the air, such as was known to precede an explosion-wave, and, since ignition was easier in a compressed gas, continue by self-ignition. Further, to make quite certain, it would be necessary to reduce the oxygen so that the most readily combustible gases produced by the distillation of coal could not be ignited.

With regard to the production of ozone by electric sparks, this was, apart from the relatively great cooling surface of the spark, one of the objections to experimental ignition of coal-dust by an induction-coil discharge. There was very little ozone produced by single low-voltage flashes in large vessels, such as those used in his (the writer's) experiments on coal-dust*; none could be detected by smell. The cases met with in practice were ignitions by single flashes, and whatever the immediate cause of dust ignition might be, it was necessary to use the kind of ignition most nearly imitating practical conditions. If he (Prof. Thornton) might offer a criticism of Dr. Harger's experimental

* "The Ignition of Coal-dust by Single Electric Flashes," by Prof. W. M. Thornton, *Trans. Inst. M.E.*, 1910, vol. xxxix., page 201.

apparatus, it would be that the explosion tube was much too narrow. He (the speaker) had found that to get consistent results a volume of at least 2 litres was necessary, and tubes about 2 inches in diameter.

He hoped that Dr. Harger's suggestion would be regarded by mining men as not impracticable, although perhaps it might require more careful continuous control than they were willing to give for the purpose. It had support from what might be called small-scale experiments, and every opportunity of trying the effect on a large scale should be given, having regard to the importance of the result. The respiration part could be dealt with without much trouble, and the influence of the magnitude of the central ignition could be tried, with the oxygen reduced, with the existing apparatus at Altofts.

Dr. LEONARD HILL (London Hospital) wrote that he had read with great interest Dr. Harger's paper. If Dr. Harger's figures were correct, concerning the percentage of oxygen necessary for the explosion of methane and coal-dust, the only difficulty in putting his plan into operation was that of obtaining an adequate supply of air, partly deoxygenated, otherwise pure and cool.

On referring to the *Investigation of Mine Air* by Sir C. Le Neve Foster and Dr. J. S. Haldane, he found it clearly stated on page 135 that 6 per cent. of methane and 12 per cent. of oxygen constituted an explosive mixture; and again on page 136 an analysis was given of a sample containing—oxygen, 14·65; carbon dioxide, 1·96; methane, 7·07; and nitrogen, 76·32 per cent.; and these words followed:—"It will be seen from the analysis that the mixture was explosive. If diluted to about half with pure air, it would probably just support a flame, and would also show a distinct cap."

There seemed to be a clear contradiction here between Dr. Harger's results and the opinion of Dr. Haldane. Supposing that Dr. Harger had proved his case, and that an air-supply containing only 17 per cent. of oxygen would prevent all chance of explosion in the conditions of temperature and pressure pertaining in a mine, there were no physiological objections to the employment of this method, which seemed to him (Dr. Hill) a most simple, safe, and effective one.

It was well known that men could work hard and live vigorous healthy lives in the mountainous regions of the earth

where the partial pressure of oxygen was 17 per cent. of an atmosphere, or less. In the Alps there were noted health-resorts at very high altitudes; and the Alpine guides and soldiers were the strongest and healthiest of men. Mexico City and Johannesburg were built at an altitude of about 6,000 feet; in the Andes, railways were built and mines worked at altitudes of 12,000 to 15,000 feet; and the populations of great towns existed at altitudes of 10,000 feet. The human organism compensated easily for the diminution in the partial pressure of oxygen.

The ventilation of the lungs and the percentage and total amount of hæmoglobin in the blood increased, and the power of the hæmoglobin to hold oxygen in chemical combination changed, with the result that the tissues obtained an adequate amount of oxygen; the only perceptible difference in an acclimatized individual at great altitudes was greater breathlessness on severe exertion.

In his (Dr. Hill's) laboratory, he had a chamber containing some 3 cubic metres of air. In this he had confined on several occasions eight students until the percentage of oxygen fell to about 16, and that of carbonic acid rose to over 4. At the same time, the air in the chamber became very warm and moist (85° Fahr. wet bulb). The discomfort felt by the students was relieved by switching an electric fan in the roof of the chamber and whirling the impure air within. The discomfort was caused, not by lack of oxygen or excess of carbonic acid, but by stagnation of body heat. The air confined in the clothes and between the bodies of the students was almost motionless, warmed nearly to body temperature and saturated with moisture. The skin (the cooler of the body) could not properly act. The blood congested in the skin, sweat bedewed the face and body, and the heart wearied of its rapid beat.

On whirling the air in the chamber (which was at 85° Fahr.), a cooling effect was produced, and this gave relief. Relief was not obtained by one within who breathed through a tube the pure air outside the chamber; and discomfort was not caused to one who outside the chamber breathed through a tube the impure air within. He (Dr. Hill) had seen the students trying to light cigarettes to relieve the monotony of the experiment, and their astonishment because the matches would go out. He had seen one lend wax-matches to another who thought that his wooden

matches were damp. The students were unconscious of the diminution in oxygen, and never thought that the matches would not burn because the oxygen was deficient. From the results of a vast amount of physiological enquiry, it was known that it was the partial pressure of oxygen which mattered—not the percentage. The breathing of 17 per cent. of oxygen at atmospheric pressure was the same as breathing 21 per cent. of oxygen at an altitude where the partial pressure of oxygen was equal to 17 per cent. of an atmosphere.

In combustion it was the percentage that mattered, while to the human being it was the partial pressure. He (Dr. Hill) could not see, therefore, any objection to the ventilation of mines with air containing 17½ per cent. of oxygen, so long as the air was free from poisonous impurities such as carbon monoxide, and was sent down in sufficient volume to keep the air at the working-faces cool and moving. The good health and vigour of the miner depended greatly on the coolness and movement of the air. He could work in such air without ever straining his heat-regulating mechanism, and such air by its cooling property promoted his appetite and his bodily and nervous health.

That ½ per cent. of carbonic acid in the air breathed had no ill effect was shown by the healthy lives of brewers who tended the fermentation-vats. He (Dr. Hill) had made observations on men who bottled up the carbonic acid in the Albion Brewery, London. The men worked in a room where there was generally an excess of carbonic acid, and they had worked in it for long shifts each day and for many years.

The excess carbonic acid in the air breathed acted on the respiratory mechanism and increased the depth of breathing, and precisely to such an extent that no excess was retained within the body. The respiration was so regulated as to keep the percentage of carbonic acid in the pulmonary air always the same, namely, about 5 to 6 per cent. of an atmosphere. Dr. J. S. Haldane had discovered this fact, and it had been confirmed by all other workers on the subject. He (Dr. Hill) saw no harm in allowing the percentage of carbon dioxide to rise to 0·5. The only effect that it could have was to increase slightly breathlessness during severe work.

Marsh-gas was as harmless as nitrogen to breathe, and its presence in the air could do no harm to the miner if the percentage of oxygen was kept below the explosive point.

The exceedingly poisonous gases, carbon monoxide and hydrogen sulphide, might contaminate mine air. Dr. Haldane had found 0·11 per cent. of carbon monoxide in a closed flask in which a freshly-mined piece of coal had been left, and there was still 8 per cent. of oxygen left in the air of the flask. Hydrogen sulphide and carbon monoxide might be formed from explosives, and nitrous fumes from the accidental ignition of dynamite. These facts must be borne in mind when considering whether the ventilation could be reduced so as to give a safe percentage of oxygen. An obvious alternative to the employment of flue-air was to allow the mine to deoxidize the air-supply —to mix the return air, after cooling, in sufficient proportion with fresh air.

He (Dr. Hill) could not lay too much stress on the importance of keeping the air-supply cool.

All the evidence went to show that men endured not only with impunity, but with splendid health, exposure to an ill-ventilated close atmosphere for some hours, so long as they were exposed to a bracing cold outside air for much of the day. The North Sea fishermen shut up their cabins and slept in air which might become so impure that a lamp went out. For a man exposed to rugged elements, fighting with wind and sea, hail, snow, and rain, it was right and proper to conserve his bodily energies for the sleeping hours in the close, warm atmosphere of the cabin, and the chemical impurity of the air had no ill effect upon him. Tame rats preferred to stay in a confined sleeping chamber if it was cold outside until the carbonic acid reached even 4 to 5 per cent.; but would come out at once if the chamber was made over warm. It was quite natural for animals that huddle together to conserve their bodily heat in holes and caves to breathe percentages of carbonic acid very much higher than those permitted by the Home Office.

Increased risk from infection resulted from daily confinement in close places. There were four chief sources of infection—(1) the inhalation of droplets of saliva expelled by coughing, sneezing, or speaking; (2) the contamination of food by excremental matter, the agency of insects, soiled hands, dust, polluted water, or milk; (3) the bites of insects; and (4) sexual connexion. Destruction of insects and cleanliness prevented (2) and (3), and the application of a suitable lotion or unguent after

connexion prevented (4). It was very difficult to guard against (1), for such infection was spread in all our public conveyances, chapels, theatres, etc., and even when men spoke to each other face to face in the open air. The main thing was to keep up our immunity against (1) by living a healthy life, and it was well known that open-air workers, such as fishermen and gardeners, had the lowest death-rate from phthisis, and rarely suffered from colds. Coal-miners occupied a very favourable position in regard to phthisis. It was essential that nothing should be done to the excellent ventilation system, now in vogue, which would lower immunity and increase the risk of infection. If the ventilation was arranged so as to give 17½ per cent. of oxygen, the air must be kept cool and moving, so as to keep up the vigour and health of the miner. The air quietly exhaled by a man was practically sterile. All the dust-particles and bacteria in the inhaled air were caught by the wet mucous membranes of the respiratory passages. He (Dr. Hill) imagined that the passages of a mine acted in the same way, and that few bacteria were to be found in the outgoing air. It had been often asserted that there was some organic chemical poison exhaled in the breath. He (Dr. Hill) had carefully sifted the evidence on which this assertion was based, and had found that there was none worthy of credence. It seemed to him an open question whether it would be better to employ purified flue-air or purified return-mine air.

One of the most interesting statements made by Dr. Harger concerned the burning of acetylene in 12 per cent. of oxygen. The acetylene-lamp gave a ready means of protecting the miner from air that was too much deoxygenated. Dr. Harger's plan would abolish the use of the safety-lamp, allow proper lighting of the mine, abolish miner's nystagmus, and make the use of electrical apparatus for haulage, etc., safe. There were consequently many points in its favour.

With regard to Dr. Harger's contemptuous remarks on rescue-apparatus, he (Dr. Hill) thought that Dr. Harger knew little of the physiological difficulties which had to be overcome. He (Dr. Hill) had worked for some years on this subject, and had invented an apparatus weighing a few pounds, costing no more than 30s., and usable by a skilled man. The difficulty was to make an apparatus which required no skilled attention, safe and cool to breathe, and such as would allow a man to give the

whole of his mind to his task. The Siebe-Gorman dress was far from being "an absurd walking fitters'-shop." Men wearing that dress had done efficient work, and safely. He (Dr. Hill) had added to it recently a large cooler, filled with carbonic-acid snow, and placed on the inspiratory tube. With the aid of this he had found men able to stand for 2 hours a wet-bulb temperature of 90 to 95° Fahr., and a dry-bulb temperature of 120° Fahr., together with the radiant heat from a coke stove in the experimental chamber.

Prof. W. Galloway (Cardiff) wrote that he had read Dr. Harger's paper with much interest. Dr. Haldane's statement to the effect that a reduction of oxygen to 17½ or 18 per cent. was immaterial for respiration might be accepted as final and conclusive on that point. It was also self-evident that as the proportion of oxygen was decreased in a mixture of coal-dust and air, the mixture would become less inflammable, and would finally cease to be inflammable, at ordinary pressure and temperature, when a certain point was reached; but that point would vary with the pressure and temperature.

He was satisfied that Dr. Harger's experiments had been made on far too small a scale to enable him to determine that point with any approach to accuracy. What effect, for instance, upon the remainder of the mixture around and above it had the discharge of the "powerful coil" employed in his apparatus when igniting that part of the mixture through which it passed? Even Dr. Harger had admitted that his method was not satisfactory and "hoped to be able to devise a better" one.

No doubt 5,000 or 6,000 cubic feet of flue-gas per 100,000 cubic feet of air per minute would effect the reduction in the proportion of oxygen which Dr. Harger imagined would suffice for the purpose that he had in view. But no guarantee could be given that the flue-gas would not occasionally contain 1 per cent. or more of carbon monoxide, owing to imperfect stoking of the boiler-furnaces. This would give about 0·05 per cent. of that gas in the air of the mine, which, according to Dr. Haldane, would produce giddiness in half an hour. It was true that Dr. Harger said that special precautions would have to be taken to prevent the formation of carbon monoxide. These special precautions

could only take the form of: first, uniformly careful stoking at every colliery—a desideratum that notoriously did not now obtain; and, secondly, the introduction of a larger quantity of air into the boiler-furnaces than at present, and, consequently, waste of heat and increased consumption of fuel. Added to these was another difficulty, namely, that of preserving a delicate balance between the quantity of flue-gas and fresh air entering the mine simultaneously; for if that balance were lost for only a short time by a diminution in the ventilation due to a fall in the workings, or to a slackening of the ventilating machine on the one hand, or of the machine used for drawing the flue-gas from the flues and forcing it into the shaft on the other, the miners would alternately be quickly poisoned or be living in a fool's paradise.

It would perhaps be instructive to traverse Dr. Harger's numerous statements regarding the conditions that prevail in mines, the mode of occurrence of explosions, and so on. But two examples of the nature of many of his arguments might suffice in this place.

First, Dr. Harger had "no doubt in his own mind . . . that the intake haulage-ways of the mine working the Barnsley Seam contain an explosive mixture of dust and air."* From this it was obvious that he did not know how much dust the air must contain before the mixture became explosive, and on this point he might consult page 68 of Messrs. Taffanel and Durr's report of August, 1911, with advantage.† He (Prof. Galloway) might mention, however, that a man could not breathe air containing the requisite quantity for many minutes without being suffocated, much less work in it for several hours at a time.

Secondly, "Large dust explosions unaided by gas are a modern production, and may be said to date from and be caused by the Coal Mines Regulation Act of 1872 and the subsequent laws passed during the last 40 years."‡ But there were many great explosions before 1872 inclusive of, and subsequent to, 1851, when Inspectors of Mines were first appointed. The number of deaths due to explosions were as follows:—

* *Trans. Inst. M. E.*, 1912, vol. xliii., page 144.

† *Cinquième Serie d'Essais sur les Inflammations de Poussières, Essais d'Inflammabilité*, by Messrs. J. Taffanel and A. Durr, 1911.

‡ *Trans. Inst. M. E.*, 1912, vol. xliii., page 148.

		Deaths.
For the year	1851 ...	321
do.	1852 ...	264
For the 10 years ending	1862 ...	2,165
do. do.	1872 ...	2,381
do. do.	1882 ...	2,629
do. do.	1892 ...	1,469
do. do.	1902 ...	1,040
For the 9 years ending	1911 ...	1,340

During this period of 62 years the number of men employed and the output of coal had both more than doubled, and the number of deep, and hence dusty, mines had vastly increased. On the other hand, the number of deaths due to explosions had been reduced to practically one-half of what they were before 1872. How then could Dr. Harger substantiate his statement in the face of the actual figures? How did he know whether all the great explosions before 1872 were, or were not, due to coal-dust? The presence of "charred timber" and "marks of burning" was mentioned over and over again by those who investigated these explosions, and these two expressions, being interpreted, might, as a rule, be taken to mean that the timber, coal, and other objects were coated with coked coal-dust just as they are found to be in modern coal-dust explosions. The investigations made during the eighth decade of last century and subsequently had for their very object the discovery of the causes of the great explosions that had happened previously to that decade, as well as those that were taking place at the time, and not of those that were going to happen during the following 30 or 40 years.

Dr. P. Phillips Bedson (Armstrong College, Newcastle-upon-Tyne) wrote that Dr. Harger had done well to direct attention to a side of the phenomena associated with coal-dust explosions, which hitherto had not received due consideration. Although in the investigation of the explosion of mixtures of fire-damp and air Sir Humphry Davy had demonstrated the inhibitive influence of carbon dioxide, and had established those facts which formed part of the common stock of knowledge, which were illustrated experimentally in lectures dealing with the properties of marsh-gas, the light of the behaviour of carbon dioxide, and reduced oxygen proportion in mixtures containing air and marsh-gas, it was not strange to find that effects were produced on mixtures of coal-dust and air such as those described by Dr. Harger. But, granting that, it did not in any way remove the

grave doubts which might reasonably be entertained as to the feasibility of Dr. Harger's proposal to supply mines with an atmosphere of the composition advocated in his paper. It was further questionable whether there was sufficient information to allow one to judge of the effect on the men of working over lengthy periods in an atmosphere containing the reduced proportion of oxygen and the increased proportion of carbon dioxide. Whilst recent experiments by physiologists showed that an atmosphere of the composition given in the paper was capable of supporting life, had they demonstrated that a man could work continuously in such an atmosphere for a shift of 8 hours without feeling any ill effects, or without influencing his output? Or, again, what would be the ultimate effect on the miners' health of the alternations between the air of the mine and the purer air at bank?

Regarding Dr. Harger's results as to the inflammability of mixtures of coal-dust and air, the writer and Mr. H. Widdas had communicated to the The Institution of Mining Engineers* an account of a method of examining coal-dusts from this point of view. In the papers referred to it would be found that the influence of the mineral content of the dust and the state of subdivision of the coal, were dealt with at considerable length, with results which led to the same conclusions as those arrived at by Dr. Harger. The ignition of clouds of dust and air by electric sparks was one which the writer tried and discarded in favour of the, to him, more satisfactory method described in the papers mentioned above.

Dr. F. C. GARRETT (Armstrong College, Newcastle-upon-Tyne) wrote that Dr. Harger's paper was of great interest, and raised many important questions; but his results differed so greatly from those of other workers that a large amount of experimental data would be required before his conclusions could receive general acceptance. For example, Dr. Harger implied that mixtures of marsh-gas and air could not be ignited by a small flame if they contained less than about 8 per cent. of methane.† Against this there was the evidence of Davy, Mallard

* *Trans. Inst. M. E.*, 1906, vol. xxxii., page 529; 1907, vol. xxxiv., page 91; and 1910, vol. xxxix., page 719.

† *Trans. Inst. M. E.*, 1912, vol. xliii., pages 149 150.

and Le Chatelier, Clowes, and Hauser, all of whom used flames as their means of ignition, and obtained figures ranging from 5 to 6¼ per cent., while the Royal Commission of 1881 recorded many explosions caused by the passage of air containing only 5½ (in some cases 4¼) per cent. of this gas over a defective safety-lamp. Dr. Harger stated that the gas which he used was impure, but gave no analysis; and possibly it was more impure than he thought. Davy had pointed out that carbon dioxide diminished the inflammability of marsh-gas, and many quantitative experiments had been made, but no experimenter seemed to have found this action to be so great as Dr. Harger suggested. Hauser had found that 4 per cent. of carbon dioxide raised the lower limit of inflammability from 6·1 to 6·5 per cent.; 8 per cent. of carbon dioxide raised it to 6·9 per cent.; and even 10 per cent. only raised the limit to 7·5 per cent. Le Chatelier had obtained somewhat smaller figures. The effect of lowering the percentage of oxygen had also been studied, and here again Dr. Harger was at variance with other investigators. Hauser,† working with air containing 4·4 per cent. of carbon dioxide, and only 15·2 per cent. of oxygen, found that the addition of 8 per cent. of pure methane gave an explosive mixture. The great importance of Dr. Harger's proposals, and the very contradictory statements made by various workers, made it necessary that the matter should be more fully investigated before any practical conclusions could be arrived at, and it was to be hoped that the author would continue his very interesting work.

Dr. HARGER wrote the following reply to one or two points mentioned in the written communications incorporated with the discussion.

There appeared to be much difference in the results obtained by various workers on the inflammability of mixtures of methane and air. There was no doubt, however, that the methane flame itself went out when the oxygen was reduced to about 17½ per cent. That fact was quite certain.

It was generally accepted that with 13 or more per cent. of methane in the air the mixtures were not inflammable, and he would like to point out to members that there was in such a mixture 18¼ per cent. of oxygen.

† *Leçons sur le Grisou*, by Enrique Hauser, Madrid, 1908; and *Annales des Mines de Belgique*, 1907, vol. xii., page 1084.

It was well known, and generally agreed upon by observers, that methane was the least inflammable of hydrocarbon or any other inflammable gases.

It would be a difficult matter to test, in a manner which would be quite reliable, whether a mixture containing so little as 12 per cent. of oxygen was inflammable. He could not see how such an experiment could be satisfactorily tried, for instance, with a candle-flame. A candle would certainly not burn in such gas; for the experiment to be carried out satisfactorily, a gas-jet or an acetylene-jet would have to be put into the mixture.

All the facts pointed to Prof. Haldane being wrong either on this point of the inflammability of methane, or on the point that fire-damp in mines was pure methane. It was to be hoped that further work would be done in this direction, and the question definitely cleared up, as it was one of vital importance to mining men. In this connexion, it might be pointed out that determinations of the lower limit showed it to be about 5½ per cent. of methane (pure methane), but the Royal Commission on Mines found that mixtures in mines with so little as 4¼ per cent. of fire-damp were inflammable.

A possible explanation of these results and apparently contradictory observations might, perhaps, be found in the fact that samples in the mines contained, in addition to the gas, very fine coal-dust. It was a fact well known to chemists that any dust would make a gas-mixture more inflammable than the same gas-mixture was without the dust; and that might be the explanation of the differences in the results obtained.

It occurred to him (Dr. Harger) that Prof. Haldane, in stating that he and Dr. W. N. Atkinson had found that mixtures of fire-damp and air were inflammable with so little as 12 per cent. of oxygen, meant that such mixtures could be *lighted* and would *burn* in ordinary air. That, of course, might be so. A mixture of 31 per cent. of methane (CH_4), 12 per cent. of oxygen (O_2), and 57 per cent. of nitrogen (N_2), when allowed to mix with 2½ times its volume of ordinary air, would give a gas consisting of 9 per cent. of CH_4, 18·3 per cent. of O_2, and 72·7 per cent. of N_2, which was, of course, inflammable or explosive in itself.

Another example of fire-damp mixed with air and black-damp was 15 per cent. of CH_4, 12 per cent. of O_2, and 73 per cent. of nitrogen and carbon dioxide, one part of which, when

mixed with 1½ parts of air, would give a mixture containing 6 per cent. of CH_4, 17·4 per cent. of oxygen, and 76·6 per cent. of nitrogen and carbon dioxide, which was a mixture on the border-line, and might just ignite or explode in itself on the application of an acetylene- or other gas-flame.

In Prof. Galloway's communication criticism was directed to the statement that certain mines contained an explosive mixture of dust and air. He (Dr. Harger) was well aware that ignitions could not occur in dust and air unless the dust was very dense; but, as was known only too well, explosions started elsewhere could be propagated by very little dust indeed.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE,

JUNE 1ST, 1912.

MR. JOHN H. MERIVALE, PAST-PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, and reported the proceedings of the Council at their meetings on May 18th and that day.

The SECRETARY read the balloting list for the election of officers for the year 1912-1913.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. FRED CUTHBERT CORDY, Engineer, 23, Bostock Avenue, Northampton.

Mr. MICHAEL FALCON, Mining Engineer, Ebbw Vale, Monmouthshire.

Mr. ROBERT KELSICK, Colliery Manager, Aberdare Colliery, Cessnock, New South Wales, Australia.

Mr. WILLIAM LEE, Civil Engineer, Stow Tate Villa, 118, Stow Hill, Newport, Monmouthshire.

Mr. ROBERT MCVEE, Colliery Manager, Premier Colliery, Shotts, *via* Collie, Western Australia.

Mr. HENRY ARCHIBALD ALLEN PHILLIPS, Mining Engineer, 11, Uplands Terrace, Swansea.

Mr. STANLEY ROBINSON, Mining Engineer, Chesterholm, North Biddick, Washington Station, County Durham.

Mr. CARLOS BERNARD ROSENPLAENTER, Consulting Petroleum Engineer, 2, Elmbourne Road, Upper Tooting, London, S.W.

ASSOCIATE MEMBER—

Mr. HERBERT MAJOR, 69, Otto Terrace, Sunderland.

ASSOCIATE—

Mr. CHRISTOPHER GEORGE HENDERSON, Mine Surveyor, 17, First Row, Ashington, Northumberland.

STUDENT—

Mr. FRANK FLETCHER, Mining Student, 11, South View Terrace, North Biddick Colliery, Washington Station, County Durham.

Dr. F. C. GARRETT read the following paper, by himself and Mr. R. C. Burton, on "The Use of *X* Rays in the Examination of Coal":—

THE USE OF *X* RAYS IN THE EXAMINATION OF COAL.

By F. C. GARRETT, D.Sc., and R. C. BURTON, B.Sc.

It is well known that the opacity of solids to *X* rays is roughly proportional to their specific gravities, that carbon and the organic compounds generally are much more transparent than the inorganic minerals which make up the ash of coal, and that the diamond can easily be distinguished from its imitations by this property. It is obvious, therefore, that if prints are taken from a radiograph of a piece of coal, the true coal substance will hardly appear, while the inorganic minerals associated with it will be seen as dark or black spots and veins. Fig. 1 (Plate IX.) is a piece of household coal containing veins and patches of calcite; Fig. 2 (Plate IX.) is a household coal with a superficial plate of calcite (showing as a grey area), and crystals of pyrites (showing as a black cross) buried in the coal; whilst Figs. 3 and 4 (Plate IX.) show the opacity caused by much ash. Fig. 3 is a piece of manjak almost free from ash, and is nearly transparent; whilst Fig. 4 is a cannel containing a considerable percentage of inorganic matter, and is opaque.

Shortly after Röntgen's discovery, it was suggested that the rays might be utilized for determining the amount of inorganic matter contained in a coal, it being thought that the opacity would be directly proportional to the ash-content of the sample. The inorganic minerals commonly associated with coal, however, differ so greatly in their permeability that it was very soon found that the opacity depended on the nature as well as on the amount of mineral matter, and the method proved to be of no practical value.

Although the *X* rays cannot tell us the amount of ash which a sample of coal will yield, it was thought that they would probably reveal its distribution in the coal, and might throw some light on the structure of the coal itself. Samples from a number of different seams were obtained, and the examination of these has given results, some of which appear to be worthy of record.

The method adopted was extremely simple. Typical pieces of coal of a convenient size were fixed, by means of putty or some similar material, in a metal holder, and blocks cut out of them by a fret-saw. At first specimens of about a cubic inch in volume were cut, but these proving to be a little too thick, rods about ½ inch square and 1 or 2 inches long were used, the saw not permitting of the cutting of longer pieces. A photographic plate was placed in a paper bag, the samples laid on top of the paper with the bedding at right-angles to the plate, and the whole exposed to the rays for about 30 seconds. After the plates had been developed and examined, the blocks themselves were broken up for examination, and finally powdered for analysis. The radiographs are of the same size as the pieces of coal used, but, of course, show objects reversed, the coal appearing light and the ash dark.

Whether the amount of ash left by a coal can be reduced by washing or blowing must depend in part on the distribution of the ash. Where this is in distinct veins or patches, a moderate amount of crushing will serve to liberate it from the coal substance, and permit it to be washed away; but if the ash is in a fine state of division, and is diffused through the whole mass of coal, it is clear that it cannot be removed unless the whole of the coal be reduced to a very fine powder, when it would have little, if any, commercial value. Figs. 5 and 6 (Plate IX.) illustrate coals of the two types, Fig. 5 representing a Durham gas-coal, containing veins of calcite, and leaving 3·16 per cent. of ash, which is concentrated and could easily be removed; while Fig. 6 is a Welsh anthracite, yielding 3·10 per cent. of ash, which, however, is diffused through the whole mass of the coal, and it would, therefore, be impracticable to improve this coal by washing. On breaking up this latter specimen, it was found to contain innumerable small crystals (the black spots in the figure), which Dr. David Woolacott believes to be tridymite. It is not suggested that a coal with only 3 per cent. of ash should be washed; the specimens were selected because they each yielded about the same percentage of ash, and that percentage being small, its distribution is very obvious.

Figs. 7 and 8 (Plate IX.) are interesting, and illustrate a coal yielding some 25 per cent. of ash, which was not greatly improved by washing. It is clear that the "dirt" is in a very fine state of division, and is disseminated through the whole mass of

FIG. 1.—HOUSEHOLD COAL, CONTAINING VEINS AND PATCHES OF CALCITE.

FIG. 2.—HOIST
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FIG. 4.—CANNEL, CONTAINING A CONSIDERABLE PERCENTAGE OF INORGANIC MATTER.

FIG. 5.—DURHAM GAS-COAL, CONTAINING VEINS OF CALCITE.

PIECES OF COAL SHOWING MUCH FINELY-DIVIDED INORGANIC FUSED THROUGH THE MASS. THEY YIELDED ABOUT 25 PER H, AND ONLY A FEW PER CENT. WAS REMOVED BY WASHING.

FIG. 9.—COAL FROM THE LITTLE HUTTON SEAM, COUNTY DURHAM.

F RIA SEAM,
PARALLEL

FIG. 12.—COAL FROM VICTORIA SEAM, COUNTY DURHAM (BEDDING HORIZONTAL, AT RIGHT-ANGLES TO THE PAPER).

the coal. Examination revealed very few distinct particles of minerals, and an analysis of the ash showed that the inorganic matter present was closely related to clay.

The radiographs prove that this method of examination will show whether a coal with a high percentage of ash is suitable for washing, and the method will probably be found to have a certain commercial value.

The study of a number of radiographs leads the writers to conclude that, although the true coal substance is almost transparent to *X* rays, there are small, yet noticeable, differences between different coals, and even in different parts of a small specimen, and to hope that a full investigation of these may throw some light on the structure and perhaps on the origin of different coals. Contrast, for example, the well-marked stratification in Fig. 9 (Plate IX.), a specimen from the Little Hutton Seam of County Durham, yielding 6·35 per cent. of ash, and the almost structureless anthracite (Fig. 10, Plate IX.) from Abercrave, South Wales, yielding 1·54 per cent. of ash. Most interesting of all is the sample (Figs. 11 and 12, Plate IX.) from the Victoria Seam, County Durham; the ash in this specimen only amounts to 1·24 per cent., but the coal itself shows a curious columnar structure, and breaks very easily into columnar fragments. The Victoria Seam yields a famous coke, and it is interesting that such a structure as this can be detected, though in a less degree, in other coking coals which the writers have examined. The number of samples examined is too small to justify dogmatism, but it seems almost as if this structure were characteristic of coking coals.

At this early stage it is not permissible to draw any conclusions as to the structure of coal, and the writers apologize for submitting so imperfect an investigation; but the departure of one of them for India prevents further collaboration, and it is hoped that the publication of these notes may lead to suggestions which will be of assistance in the further investigation of the matter.

The writers are greatly indebted to Mr. C. A. Seyler, of Cardiff, and Mr. F. R. A. Shiel, of Burnopfield, for their kindness in providing specimens of known origin; and to Dr. W. D. Arnison for placing his *X*-ray apparatus at their disposal.

Prof. G. A. Lebour (Armstrong College, Newcastle-upon-Tyne) wrote that the paper was one of great interest, more especially as it opened out the prospect of a new method of investigating coal, which seemed to promise rich results. It was clear that they had now a simple method of determining the mode of aggregation and distribution of the particles of inorganic substances which made up what was called the "ash" of coal. This must be of real practical value, and no doubt would be carefully tested by those who had experience in the separation of coal from its impurities. From a purely scientific point of view, however, the interest was perhaps still greater. There were two or three kinds of "ash" in coal. First, there was the foreign matter which was brought by wind from beyond the boundaries of the ancient forests or swamps of coal-plants, or which fell incorporated in rain-drops, and might be called the "dust" variety of "ash." Next, there was that mineral matter which formed part of the living plants, such as the silica in horse-tails, the amount and nature of which would vary according to the relative abundance of special kinds of plants—there would necessarily always be a certain percentage of this "ash" in all true coals—and it might be referred to as the "native ash." Lastly, there must generally be present more or less mineral matter due to the formation of new compounds from the decomposition and reconstruction of both the native and the dust "ash." Further *X*-ray examination of coal might very probably lead to a possible discrimination between these forms of "ash," and thus to a very valuable addition to our still scanty knowledge as to the detailed processes connected with the growth of coal-seams. The careful selection of specimens, with exact particulars as to the orientation of the radiographed lumps and the position which they occupied in the seam of origin, would be of the first importance. He (Prof. Lebour) suggested that very minute study of the thin, and often commercially valueless, bands of shale, or carbonaceous shale, so often found interstratified with the good coal, should be carried on simultaneously. It should be remembered that each band of this kind represented an interruption in the steady growth of a coal-seam, due in most cases, probably, to temporary flooding by water, but sometimes also, possibly, to earth-movements, or to such occurrences as dust- or sand-storms. He did not know whether prac-

tised observers by working some considerable time with the Garrett-Burton method might hope to be able actually to determine the different minerals by the relative intensity of their shadow; but he imagined that acquired skill might enable this to be done—at any rate, in regard to some of the leading minerals involved, and those were not many in number. He was pleased that a field of new work so promising should have been entered upon at Armstrong College, and trusted that the authors might be enabled to follow up and bring to a successful and fruitful issue the labours which they had so well begun.

Mr. H. Stanley Atherton (Bolton) wrote that he was especially interested in Figs. 11 and 12, and also in Fig. 7 (Plate IX.). There was no doubt that these would be both interesting and useful in the further examination of the structure of coal, and he was sure that with sections prepared similar to those made by Mr. Lomax,* they would be able to acquire much more definite information. He had known for some time the advantage of using the polariscope with rock and mineral sections, and had often used it on coal sections, especially the more recent ones that had been cut so much thinner than formerly. It would be an advantage, he thought, to have a short description of the *X*-ray apparatus added to the paper, so that others working on the same lines might obtain the use of similar apparatus, as this would enable a better correlation of the results.

Mr. David Burns (Carlisle) wrote that the appearance of this interesting paper so soon after that of Mr. Lomax's looked as if a determined attempt was being made to find out what coal really was. Comparing the figures in the two papers, one could scarcely imagine that the two methods of investigation were dealing with the same substance. A series of observations made by both methods on the same piece of coal could not fail to be valuable, and go some way to eliminate false inferences. This line of investigation seemed well worth following up, commencing with an exhaustive series of radiographs of as fine carbon as could be got, from as many sources, and in as many states of compression, as possible. With these standards for

* See "The Microscopical Examination of Coal," etc., by James Lomax, *Trans. Inst. M. E.*, 1911, vol. xlii., page 2, and plates i. to xii.

comparison, fresh light would be thrown on the origin of coal. In the meantime, they could only marvel that a seam of coal could be found with less ash than the vegetable matter from which it was supposed to have been derived. Figs. 2, 6, 7, 8, and 10 (Plate IX.) were interesting, as showing that the ash was extraneous to the coal, like a mote in a man's eye. He would like an explanation of the opening sentence in the paper: were they to infer that the diamond was of organic origin?

Prof. P. Phillips Bedson (Armstrong College, Newcastle-upon-Tyne) congratulated Dr. Garrett and Mr. Burton upon the results of their investigations. Earlier attempts to use the *X*-rays for the purpose of estimating the amount of ash in coal failed for reasons which were quite apparent, as set forth in the paper; but the use of the rays to ascertain the distribution of the mineral matter in coal was proved by the paper to be one of very great service.

Mr. W. C. Blackett (Sacriston) endorsed Prof. Bedson's remarks. It certainly seemed to him that the method might, at any rate, be of use to those interested in the opening out of new seams. He did not suppose that they in this worn-out old portion of the world would have very much use for that kind of thing, as they already knew what to do with their coals, whether to wash them or not. He could, however, imagine that in fresh fields samples of coal could be picked up from outcrops and the like, and brought home, when one could first of all find out their composition by analysis, and then utilize this new method to ascertain how the ash existed. At the same time it should be remembered that stone, which was difficult to see with the naked eye, would be equally difficult for an ordinary industrial washer to separate from the coal. Figs. 11 and 12 (Plate IX.), showing the columnar structure of the Victoria Seam, were, he thought, very interesting, and might well be the subject of further consideration. He would hesitate to say that, because they found columnar structure, they were, therefore, likely to find good coking coals, as he thought was suggested by the authors of the paper. The columnar structure was perhaps due to pressure, and such pressure might only arise among strata, the conditions of deposit of which, as to climate and soil, were

favourable only to the formation of excellent coking seams. Pressure, however, might exist in seams without these conditions, and therefore without these special coking qualities.

Mr. R. L. WEEKS (Willington) said that it would be exceedingly interesting if the subject were carried a little further, and the *X* rays directed upon coke, the produce of proved seams.

Prof. HENRY LOUIS (Armstrong College, Newcastle-upon-Tyne) thought that the method was a promising one, and he did not at all despair of its being industrially useful, as well as of scientific interest. Practically one of the first things one wanted to do when one got a sample of coal, and was asked for an opinion as to whether it would wash, was to find out how fine to crush it, and he thought that this method opened out a decidedly useful field of investigation. His own view was that, in order to make it practicable, radiographs ought to be taken in two planes at right-angles one to the other: otherwise, of course, a thin sheet of mineral, which might break up very readily on crushing and give them very fine dust indeed, could not be distinguished from lumps; whereas if they took two views in planes at right-angles, they had the dimensions of the particles with which they were dealing, and that helped them in deciding how to start.

Dr. F. C. GARRETT (Armstrong College, Newcastle-upon-Tyne) thanked the members for the way in which they had received the paper. As he was not a coal-miner, but only a chemist, he was perfectly well aware that there were numberless pitfalls spread around him, and he had no doubt that he had made some mistakes.

He agreed with Prof. Lebour that it would be advisable, in practice, to get out all the minerals present. One needed to have a good deal of practice, and he had not had enough yet to speak with certainty; but he did think that the difference between calcite and pyrites could be detected, and the minerals present ascertained by their shadows.

Mr. Burns had misunderstood his opening sentence, that the diamond was of vegetable or organic origin; he did not mean to imply anything of the kind, and it did not appear to him that the sentence conveyed that; if it did, it was wrong.

He was interested in Mr. Blackett's remarks. He did not wish to speak at all positively, but the curious point was that when he was examining the radiographs of the coal from the Victoria Seam, he knew it was good coking coal, and wondered whether there was anything essential in the structure. He went to work on a number of prints, and picked out those which showed any trace of this structure, and put them on one side. He found on turning up the notes which he had concerning them that they were all coking coals, and that was why he said that it might be possible that it would prove to be a characteristic. It reminded him of a rather similar structure found in bitumens, ascribed to "pressure" (or by some to movement) in the seam. Whether that would hold good or not he did not know. He had had in mind, when he spoke so cautiously, a deep vein in Trinidad, which showed columnar structure for 6 feet from the walls, while the central portion (the same piece) showed no such structure, so that it might be that he had got upon the wrong track.

He agreed with Prof. Louis that one must take two radiographs at right-angles, as he had done in the case of the Victoria Seam coal. He had hoped to have done so all through, but, of course, it was understood that the present experiments were only preliminary ones. For this reason he did not think it worth while to give details of the apparatus used; these he hoped to supply at a later date.

The CHAIRMAN (Mr. John H. Merivale), in proposing a vote of thanks to the authors, said that the paper was perhaps one which it was difficult for them to discuss, as the bulk of the members knew very little about the subject. It was rather interesting, he thought, that they should have had two papers, one by Mr. Lomax and the other by Dr. Garrett and his collaborator, on the same subject at the same time. He did not quite agree with Mr. Blackett's remarks; he thought that the method might prove to be of considerable use even in an old country like England. He trusted that the subject might be carried further, and that both Dr. Garrett and Mr. Lomax would use their best endeavours to do so. Of course, usefulness was not everything: there was an interest in the solution of these scientific problems which he was sure appealed to them all, apart from monetary

considerations. He was sorry to learn that Dr. Garrett was to lose his collaborator, Mr. Burton, but hoped that he would find someone else who would collaborate with him, and that this would only be the first of a series of papers which they would have on the subject. He had been interested and surprised to learn how very small was the percentage of ash apparent in the radiographs; $2\frac{1}{2}$ or $3\frac{1}{2}$ per cent. was most distinctly visible, which showed how delicate the determinations could be. The investigation seemed to him to be a very helpful one.

The vote of thanks was carried unanimously.

THE MINING INSTITUTE OF SCOTLAND.

GENERAL MEETING,

HELD AT HERIOT-WATT COLLEGE, EDINBURGH, JUNE 15TH, 1912.

MR. JAMES HAMILTON, PRESIDENT, IN THE CHAIR.

The minutes of the Annual General Meeting were read and confirmed.

The following gentlemen, who had been duly nominated, were elected:—

MEMBERS—

Mr. ALLAN A. ARMSTRONG, Brixton Hill, West Calder, Midlothian.
Mr. ARCHIBALD BLYTH, Bent Colliery, Hamilton.
Mr. GEORGE LITTLE BROWN, Ryall Park, Broxburn, West Lothian.
Mr. SAMUEL A. JONES, Lethbridge, Alberta, Canada.
Mr. WILLIAM LOUDON, 11, Elliot Street, Dunfermline.
Mr. ANDREW HARDIE PEEBLES, Hawthorn Cottage, Stenhousemuir, Larbert, Stirlingshire.
Mr. HENRY POSTLE, Rosehill, Denny, Stirlingshire.
Mr. ALEXANDER REID, Compañia Carbonífera, Curanilahue, Chile.
Mr. GIRVIN HAMILTON RUNCIE, Den Cottages, East Wemyss, Fife.
Mr. JOHN WILSON, Gauchalland Colliery, Galston, Ayrshire.

ASSOCIATE MEMBERS—

Mr. ROBERT KERR, Barncluith Road, Hamilton.
Mr. JAMES MAIN, Bonnybridge, Stirlingshire.

ASSOCIATE—

Mr. ALEXANDER BOWIE, Minas del Marquesado, Alquife por Guadix, Provincia de Granada, Spain.

STUDENT—

Mr. JAMES PRENTICE KINCAID, Mining Student, Langside Road, Bothwell, Lanarkshire.

Representatives of the Institute on the Council of The Institution of Mining Engineers were nominated.

DISCUSSION OF MR. HENRY BRIGGS'S PAPER ON "TESTING FOR FIRE-DAMP AND BLACK-DAMP BY MEANS OF A SAFETY-LAMP."*

Mr. JAMES BLACK (Airdrie) wrote that during the last few years a considerable amount of research work had been carried out, with the object of discovering the effect produced by known small percentages of fire-damp upon the flame of a safety-lamp. So much had already been written on this subject that one could readily conceive the difficulty of breaking new ground. In view of this, he thought that Mr. Briggs was to be congratulated on the results of his investigations.

With a view to testing the utility of the loop as a means of detecting small percentages of fire-damp, Mr. John Wilson and he had conducted a series of experiments in the Mining Laboratory of Airdrie Academy. The results that they obtained were identical in every respect with those recorded by Mr. Briggs in his paper. The cap produced by ½ per cent. of coal-gas was quite distinct, and could be readily observed by any person possessed of normal sight. When only ¼ per cent. of coal-gas was present, the cap was very pale—it was very near the vanishing-point—but was capable of detection by any person who had had experience in gas-testing and was possessed of ordinary eyesight.

To test the device further, two veteran colliery firemen, who had had a course of instruction in gas-testing, were invited to make some observations. As a result, it was found that these firemen could detect the presence of ½ per cent. of coal-gas with absolute certainty, but that they could not always observe the cap due to ¼ per cent. Throughout the experiments, when the testing-flame was properly adjusted, they failed to observe the fuel-caps referred to by Prof. Latham at the last meeting of the Institute.†

He was now quite convinced that the loop was a simple, efficient, and practical device for detecting small percentages of fire-damp in mines. The curves showing the lengths of caps obtained with coal-gas and methane respectively were very instructive and interesting. The fire-damp found in mines varied greatly in composition, and would, no doubt, give a less

* *Trans. Inst. M. E.*, 1912, vol. xliii., pages 64 and 232.

† *Ibid.*, page 235.

length of cap for a given percentage than the almost pure methane used by Mr. Briggs. It seemed from this that coal-gas gave sufficiently accurate results for all practical testing purposes.

Mr. W. Walker (H.M. Inspector of Mines, Edinburgh) said that he had read Mr. Briggs's paper with much interest, and was sure that it, as also the discussion which it had received and would further receive, would be useful to all concerned with mining: especially so at the present time, when colliery managers and others were considering the question of the standard of ventilation with which it would be necessary to comply under the new Mines Act. Any ready means for enabling those connected with the management of mines to detect, with any degree of certainty, small percentages of fire-damp and black-damp would be a boon to managers and others. The use of a metal for cooling the flame of a safety-lamp and thereby destroying its luminosity was, he thought, not by any means new. For many years, officials, after lowering the flame to a certain extent, had made it a practice to insert the pricker into the flame, and this, in a less degree, had the same effect as Mr. Briggs obtained with the copper loop which he had adopted.

There was no doubt that Mr. Briggs's device was most useful for the detection of fire-damp, and should be the means of more thorough examinations for that gas being made, as it removed to a great extent the liability of the light of a lamp being lost in the process of lowering the light. These examinations, if properly conducted, were often made under trying conditions: it might be in wastes or in cramped positions; and personally he (Mr. Walker) had always felt that the examinations were not, as a rule, made with a lowered light.

Mr. Briggs's device also did away with the necessity of a Davy lamp being used for examination purposes, a result much to be desired. In his opinion the Davy as a lamp for detecting gas had always been much overrated, and in mines where there was any quantity of gas, if a fall or other cause created an abnormal velocity in the vicinity of the lamp, it was a distinct source of danger. The lamp described by Mr. Briggs was much superior, and possessed the advantage of being safe in all conditions under which a safety-lamp should be used.

The advantage of the lamp with the device described attached to it as an indicator where there might be a small quantity of gas

present was very great. Instead of safety-lamps with full flames being hung up, with the expectation that such a lamp would give a ready indication of the presence of gas, one of the lamps suspended in the way described by Mr. Briggs, especially where electric plant was in use, would be useful.

Recently in evidence in a law-court it was stated, in all good faith, that there was no gas in a place where an explosion occurred, because no indication could be seen on the full flame of a safety-lamp.

The use of the loop as an indicator of carbon dioxide was new, and, if it could be depended on, would be most useful; but Mr. Briggs was evidently not too sanguine of its success in all cases.

The Council of the Institute might, with advantage, appoint a small and representative committee to experiment in mines with the loop and report the results obtained. He (Mr. Walker) hoped that this would be done, in order to decide whether Mr. Briggs's device was all that he claimed it to be. He would also suggest that the members of the Institute should assist Mr. Briggs by trying the device in actual practice, and by keeping a record of all investigations.

Recently, along with three members of the Institute, he had made some observations with loops in lamps burning different kinds of oil. With impure oils the fuel-cap was much in evidence, but when pure colza was the illuminant, it was so small as to be negligible. Prof. Latham's experience must, in that respect, be due therefore to the circumstance that he had used an impure oil. All present at these observations were agreed that the gas-cap was visible with $\frac{3}{4}$ per cent. of fire-damp, but below that quantity opinions were equally divided: two could not see a smaller quantity than $\frac{3}{4}$ per cent., while the other two were able to detect a small cap with $\frac{1}{4}$ per cent.

Even if the loop made $\frac{3}{4}$ per cent. discernible with a 2 to 1 mixture of colza and paraffin, it constituted a step in the right direction, and really met all ordinary requirements.

Mr. Peter Milligan (Gorebridge) said that lately in the Heriot-Watt College, through the kind invitation of Mr. Briggs, he was privileged to witness gas-tests made by Mr. W. Walker and Mr. C. L. Robinson (H.M. Inspectors of Mines). The lamp

used was one of Messrs. Davis & Son's A1 fireman's lamps, fitted with the Briggs loop attachment for testing gas; and most of the experiments were made with oil consisting of 2 parts of pure colza and 1 part of paraffin. With 1¼ per cent. and 1 per cent. of gas the caps were very distinct, and with ½ per cent. the cap was quite visible, whilst with ¼ per cent. the cap could be distinguished. With this oil a fuel-cap could hardly be detected, although a certain haze was discernible on the edge of the flame.

A lamp from a Fife colliery, burning colza oil with one-third of paraffin added, showed a distinct fuel-cap. With the addition of 1 to 1¼ per cent. of carbon tetrachloride to the fuel in the lamp, the caps were much more distinct. The tests were very interesting, and to his mind most convincing.

It seemed to him that the standard of the quality of the colza oil used would have an important bearing on the correct reading of the caps, and his experience of colza oil was not reassuring. He had always found that oil which had been in Glasgow was far from being pure, and gave off a large volume of black smoke in burning.

Seeing that the safety of the underground workmen and the mines depended so much on good and careful examination, perhaps something could be done to standardize the quality of the oil to be used in safety-lamps, in the same way as the food of the people was standardized at the present time.

Mr. Robert McLaren (H.M. Inspector of Mines, Airdrie) said that for many years he had held the opinion that the question of the detection of gas had not received the attention that it ought. He had been privileged to see Mr. Briggs's loop in operation, and it appeared to him to do everything that was required of it. He was not, however, sure as to the scientific principle of the loop, because it seemed to him that if the loop was kept over the flame of the safety-lamp for a lengthened period, it would lose its entire power. The same thing, as they knew, happened in the case of a safety-lamp. If they had a large flame in a safety-lamp, they found that when the gauze became too much heated the power of the lamp was entirely lost, and they might as well have a naked light in an explosive mixture.

The question of oils was a very important one, and from the

demonstration they had seen that day it would appear that Prof. Latham had failed to procure pure colza when making his experiments at Glasgow University. That was a very common mistake, although not so common as it used to be. They had to be very careful in distinguishing between caps, and, if they did not have proper oil, then a fuel-cap was apt to be mistaken for a gas-cap.

Referring to the remarks made by Mr. Walker with regard to the Davy lamp, he might say that some of his colleagues were greatly in favour of that particular lamp. Not long ago he had been accompanied by a mining expert—an Inspector of Mines—and in making an examination of a mine that Inspector would have nothing else but the ordinary Davy lamp. He, personally, had a great deal of sympathy with those who favoured the Davy lamp; indeed, if the lamp were kept in good condition and the necessary care exercised, the Davy lamp was quite a good lamp for testing for gas. With some of the newer lamps they could perhaps test much better, but he did not think that the Davy lamp should be condemned altogether, because if it was properly taken care of it would often prove to be very useful.

He thought that it was a good idea for a small committee to go into the matter of the loop, and bring out a report on the subject. The committee could say whether the loop could be used and depended upon by firemen in going round the places, and could also report as to the classes of oil that were best suited for its use. There was no doubt that it was a great temptation to a fireman, if he was in a hurry in the morning, to avoid the trouble of lowering his flame in every instance. It was a process which took a little time, but with Mr. Briggs's device all that he had to do was to turn the loop across the flame. One thing to be said in favour of Mr. Briggs was that he had been able to show an experiment wherein, by putting a chemical mixture amongst the oil, the flame was very much intensified and the cap much more easily seen. If an arrangement like that could be carried out, it would undoubtedly be very helpful. Anything that would tend to make the examination of the fireman in the morning easier, simpler, and more accurate was to be recommended; and on that ground they had much reason to be very grateful to the author for having brought before them his simple yet effective invention.

Mr. J. Balfour Sneddon (Mid-Calder) said that he was one of the quartette who, on a kind invitation from Mr. Briggs, were present at the demonstration which had been already mentioned. He could therefore endorse everything that had been said by Messrs. Walker and Milligan. It did, however, seem to him to be rather a curious fact that the two to see the caps at the lowest percentages both wore glasses, while the other two who failed to see the caps at ½ and ¼ per cent. did not. He was quite convinced that Mr. Briggs had established his claim that he had a device which was really worth consideration, and he quite agreed with Mr. Walker that further experiments and demonstrations would be of value. So far, he had not yet heard that any member had tested the loop underground, and, therefore, he might explain that he had been favoured with a visit from both Messrs. Briggs and Wilson. The loop behaved well enough underground, and on that occasion he believed that he saw a cap. Evidently he (Mr. Sneddon) must have been more in his element underground than on the surface. Frankly, however, he did not think that that was altogether imagination, as he had no doubt that the average miner, after being several hours underground, where the light was steady and continuous, would find that his eyes adjusted themselves better so as to be more capable of detecting caps than at any other time. Mr. Briggs had said then that the analyses disclosed something like ¼ per cent. of gas.

Mr. C. L. Robinson (H.M. Inspector of Mines, Kirkcaldy) said that he had used Mr. Briggs's lamp in three different collieries, and he was present when the tests, which were mentioned by Mr. Walker, were made. Further, he was one of those who could not see ½ per cent. in the test-room, although he had been able to observe a cap at ¾ per cent. From his notes he observed that in the mine he was not able to see a cap with 0·82 per cent., and the same applied to 0·85 and 0·77 per cent. On those occasions, previous to giving his own opinion, he had asked the officials who were with him whether they could see anything, and they had stated that they could not. He had made a test, also, with a Wolff safety-lamp, burning naphtha, and found that he could detect a cap sooner with that lamp than with Mr. Briggs's wire when burning an oil consisting of 2 parts of colza and 1

part of paraffin. He held, as he had always held, that the detection of caps at low percentages depended largely on the oil used, and he would like to know what results the author obtained with naphtha, as he felt sure that by its use he would be able to show a better cap at a lower percentage. He (Mr. Robinson) had lost his light once or twice, as there was a little black-damp present, and, when that was present, he thought that one ought to be careful how one brought the loop into the flame. He rather thought that the reason why one could not see so clearly underground as in the testing-room was because one was in the mixture all the time underground and not switching the gas off and on as in the testing-room. Personally, he did not say, nor had he ever said, that there was an oil-cap on the lamp. What he did say was that he could not see a gas-cap up to the percentages that he had stated, while, above that, he could distinctly see a cap. He rather disagreed with Mr. Sneddon when that gentleman said that he could see a cap with a lower percentage of gas in the mine than in the laboratory. His experience was the very reverse of that, and he had tested the loop in three collieries, and when different managers and officials were present. With regard to what had been said as to firemen testing for very low percentages of gas, he would like to remark that it was not the fireman's business to decide what the percentage was. If the fireman only found a small percentage of gas in the air-current, it was his duty to report it, and another man's work to find out what the percentage was.

Mr. G. L. Kerr (Glasgow) said that the point raised by Mr. Walker in regard to the pricker of the lamp recalled to his mind what he did when he was a fireman in the Lanarkshire coal-field. The practice then was to put the pricker over the flame, so as to allow it to extinguish itself as far as possible. In that way, with a Clanny lamp, it was possible to detect gas very much more quickly than by waiting to draw down the flame. He thought that that practice was well known to all who were accustomed to the fireman's duties. Mr. McLaren seemed to think that too little attention had been paid to small accumulations of gas, but he (Mr. Kerr) thought that they ought to distinguish between accumulations and percentages of gas. Although possibly sufficient attention had not been paid to small accumulations of gas,

there was a danger of placing undue importance on this point. What did a fireman want to know about ¼ or ½ per cent. of gas in the face of the brushing or in the general body of the air? He asked that question particularly in view of the provisions of Rule 67 of the new Mines Act. By that rule men need not be withdrawn from a place until there was 2½ per cent. of gas present, if working with safety-lamps, and 1¼ per cent. if working with naked lights. They ought to be careful before appointing any committee to standardize percentages which a fireman could detect, because they might have the Home Office stipulating that if ¼ or ½ per cent. was detected, that fact would require to be entered in the report-book. Some 5 or 6 years ago he had examined a mine after an explosion in company with two Inspectors of Mines. Each of them carried a safety-lamp, while one of the Inspectors had a special fire-damp detector. With the exception of one Inspector, they could find no gas present with the safety-lamp, but that official was positive on the point that there was gas. In proof of that he examined with his fire-damp detector, and the hydrogen-flame showed what would be about ⅛ per cent. of gas present. His (Mr. Kerr's) point was this, that if they carried matters to such a fine point as that, they would get a small percentage of gas in a large number of mines. If there was ¼ or ½ per cent. in the return airway, it might be a guide to the manager, but in the general body of the air, or at the face of the brushing, it was a different matter, and they should not create a feeling of danger when there was really none present.

Mr. Henry Briggs (Edinburgh) said that he was greatly indebted to Prof. Arthur Smithells, of Leeds University, who had made a special study of flames, for the interest which he had expressed in his paper, and for his very valuable suggestions, particularly as to the reason for the flattening of the curves. As Prof. Smithells had pointed out in his letters to him, when a flame was placed in a mixture of inflammable gas and air, three cap-forming influences became operative, and the cap produced was due to the sum of their effects. These influences were (1) that of the flame, which, by radiating heat, caused a cap to form about it; (2) that of the burning gas in the cap itself, which by generating heat was able to increase its own length and volume; and (3) that of the fuel-cap, which, although

generally invisible in fresh air, was present with most fuels, and added itself to the bulk of the gas-cap. In order to comprehend their joint effect, it was necessary to consider these influences separately, and an attempt was made to do this in the subjoined figure in the text. The graphs were not set forth as accurate; they ought to be taken merely as expressing a working hypothesis, since no method had yet been devised to separate

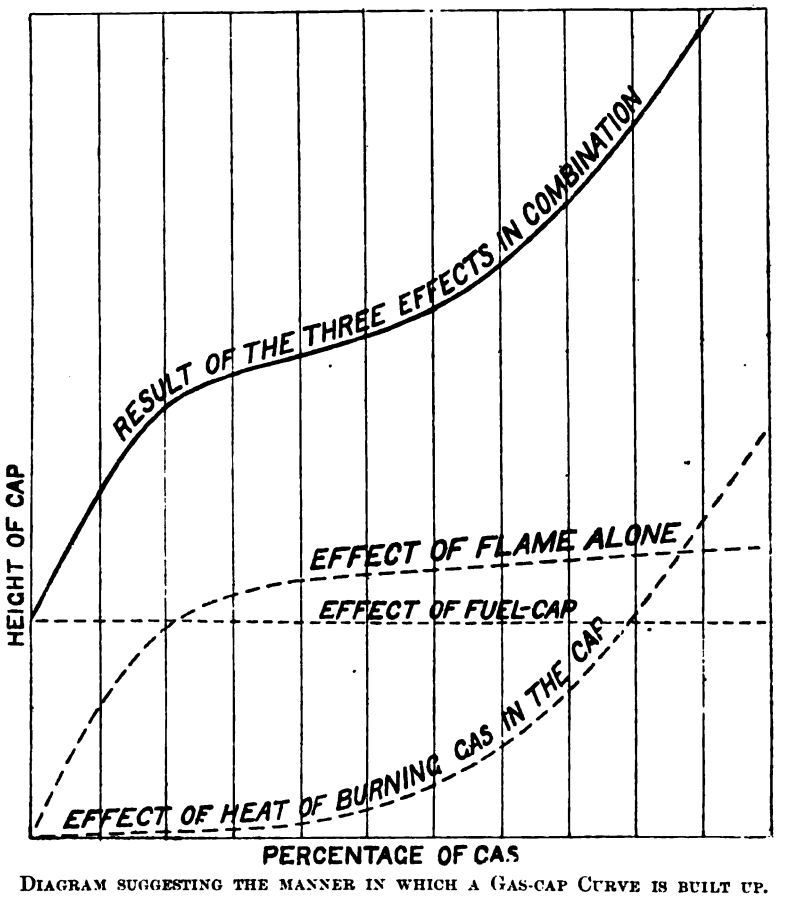

RESULT OF THE THREE EFFECTS IN COMBINATION
EFFECT OF FLAME ALONE
EFFECT OF FUEL-CAP
EFFECT OF HEAT OF BURNING GAS IN THE CAP
HEIGHT OF CAP
PERCENTAGE OF GAS

DIAGRAM SUGGESTING THE MANNER IN WHICH A GAS-CAP CURVE IS BUILT UP.

these influences one from the other in such a way that their different cap-forming powers might be measured; yet he thought that the *form* of the curves was substantially correct. It seemed probable, for example, that the curve labelled "effect of flame alone" would flatten out in the manner illustrated. The temperature-gradient must be a sharp one in proceeding outwards

from the boundary of the flame. Hence, once the cap had been capable of extending itself a little distance from that boundary, a further increase in the proportion of gas, say from 3 to 4 per cent., would not seem likely to result in more than a small increase in the cap-length produced by this cause alone. There was even less doubt as to the influence of the burning gas in the cap: for, as the heat generated by the combustion of the gas must increase more and more rapidly as the gas-percentage increased, it followed that the curve illustrating this effect would become steeper towards the explosive limit. Indeed, it was known that at that limit the heat so produced was such as to render the combustion self-supporting; or, to use the phraseology of the mathematician, an ordinate at the percentage representing the explosive limit must be asymptotic to the curve in question. The effect of the fuel-cap was represented as a level straight line, since it would seem probable that the fuel-cap could do no more than lift the resultant curve (shown by a full line) bodily away from the horizontal axis by a distance equal to its height. The full line was plotted by adding the ordinates of the three lower curves, and it was seen that its character was much the same as that of the graphs contained in his (Mr. Briggs's) paper.

While it was possible that the method of flame standardization employed tended slightly to accentuate the flattening of the curves, it seemed to him that Prof. Smithells's explanation was likely to be correct, and he thought the point new and valuable. Some recent tests had gone to strengthen his view that the flattening was a normal feature of all such curves, whether the results were obtained by the aid of the loop or not; but the difficulty of getting trustworthy measurements of caps for percentages below 1¼ with the lowered flame was very great.

Prof. Smithells had also forestalled him in having used a copper-wire ring for deluminating a flame, although he did not seem to have put it to actual use as a means of detecting gas. He referred to the wire ring in a paper published in 1892 in the *Journal of the Chemical Society*, and gave a figure showing the effect of introducing the ring into a small flame. He was also able to prove that the metal ring, by tapping some of the heat, did not merely prevent the incandescence of carbon particles, but actually interfered with the separation of solid carbon.*

* *Journal of the Chemical Society*, 1892, vol. lxvi., pages 217 and 224.

Prof. Latham, in his remarks on the loop device, had stated the results of certain experiments made at Glasgow University.* He had found the gas-caps for percentages of coal-gas less than 1½ to be so completely masked by tall fuel-caps as to be quite undistinguishable, and had come to the conclusion that the loop was therefore of no service in detecting these small proportions. The members had had the opportunity, prior to the meeting, of seeing the loop used with oil obtained from the merchant supplying Glasgow University, and they had seen that with that oil Prof. Latham's claim was substantially correct, a particularly strong fuel-cap being observed in fresh air. They had also examined similar lamps, burning oils obtained from other sources, and had found no such fuel-caps discernible.

The reason for the difference was that Prof. Latham was using in his laboratory impure colza containing a product capable of acting on the copper of the loop, the effect of the reaction being to render the fuel-cap easily visible. The proportion of impurity was probably small; yet its importance had to be judged from its effects rather than from its amount. While no one could object to the Glasgow University buying impure oils, the assumption which underlay Prof. Latham's criticism, namely, that others must be doing the same, constituted the first and gravest of his mistakes. In undertaking any experimental enquiry, the first step was to make sure that one's materials were above suspicion, or otherwise, as Prof. Latham's tests exemplified, interfering agencies might enter, and the results be rendered untrustworthy.

The fact was that the copper loop produced no *visible* fuel-cap when mixtures of paraffin and pure colza in any proportions were used. That there was an invisible fuel-cap he was quite sure, and he had endeavoured to make the fact clear by the curves illustrating his paper.† This invisible fuel-cap added its body to that of any gas-cap present, and rendered the latter larger and more distinct; yet in fresh air and with pure oil, as the members had observed that day, nothing was to be seen above the loop resembling the cap produced by, say, ¾ per cent. of fire-damp.

Prof. Latham had stated‡ that both he and Mr. Hunter "had

* *Trans. Inst. M. E.* 1912, vol. xliii., page 235.

† *Ibid.*, pages 68 and 70. ‡ *Ibid.*, page 237.

found it to be a matter of the utmost importance to swing in the loop at the right position " in the flame. As an actual fact, it did not matter in the slightest at what position the loop was swung into the flame, provided that it was inserted symmetrically, and was then adjusted, together with the wick, to give the standard flame. What the standard flame was for fire-damp testing, and how to get it, he had mentioned three times in his (Mr. Briggs's) paper.

Prof. Latham's criticism of the black-damp indication would have been of more value had he tried the test, which he evidently had not. In referring to the fact that, as stated in the paper, the presence of an amount of black-damp in excess of the permissible proportion was not capable of detection by the loop if fire-damp was also present, Prof. Latham proceeded to argue upon the premises that the loop was unable to reveal such small proportions of fire-damp as would be capable of masking the black-damp indication; yet, had he used pure colza in his lamp-oil, he would have found no difficulty in discerning the percentages of fire-damp in question. He had then assailed the black-damp indication as being, in his opinion, too inaccurate for practical purposes. His remarks as to the variability of the composition of black-damp merely confirmed his (Mr. Briggs's) own, and the difficulty arising from this was admitted by him (Mr. Briggs) in the first sentence, dealing with tests for black-damp, in his paper.* To this extent they agreed; but when Prof. Latham attempted a *reductio ad absurdum* from that fact, he (Mr. Briggs) was again obliged to take the opposite view. If, argued Prof. Latham, the shape of the loop was to be modified to suit the composition of the black-damp present, it would be necessary, " in order to know with anything like accuracy " whether " the experimenter " was using the correct shape, " to make a chemical analysis of the black-damp before he could make the loop test at all." His answer to that, and to the two paragraphs which followed, was that his critic had missed the fact that the loop contrivance was primarily designed for the fireman; and that, although a delicate means of indicating fire-damp, it was intended to serve, not as a substitute for analysis in the detection of black-damp, but to assist the fireman in carrying out his statutory duties

* *Trans. Inst. M. E.*, 1912, vol. xliii., page 72.

in respect of ventilation. His view, subject to correction by H.M. Inspectors of Mines present, was that it was outside the province of the fireman to attempt precise analysis of the air of his district, but that his duty was to bring to the notice of his superiors a state of affairs which tended towards an infringement of the Act. He (Mr. Briggs) claimed that the loop would aid the fireman here, so far as black-damp was concerned, and that if he should find the flame "shy" when the loop was brought across it—and anyone who had tried the device when black-damp was present in considerable amount would know what was meant by that expression—it was time for him to report the fact, in order that the air might be tested by a more refined method. Having regard to the character of this test, it would, he believed, be sufficiently exact for practical purposes to make the loop suit the average character of the black-damp present in a seam, as determined, say, from several samples obtained in different places at intervals of a week. Should the analyses of the samples show the composition of the black-damp to vary between exceptionally wide limits, he would be the first to discourage the use of the loop device in that connexion.

Most of Prof. Latham's argument as to the difficulty of getting precise results in black-damp testing applied with equal force to Dr. Haldane's tube-and-taper test; for he found that although that test gave excellent results with saturated air contaminated with black-damp containing about 13½ per cent. of carbon dioxide, yet—to proceed to extreme cases—9 per cent. of pure nitrogen was registered as 7 per cent., and 9 per cent. of pure carbon dioxide as 9¾ per cent., by the taper. Did it, therefore, follow that the results obtained in practice by Dr. Haldane's tube were likely to be "utterly erroneous" and valueless? He (Mr. Briggs) thought not.

The question of the strength of the loop was one on which he had spent a good deal of thought before writing his paper, and he came to the conclusion that the fact of the loop being easily bent was of little practical consequence, and so far he had found no reason to modify it. Prof. Latham had stated that he had experienced considerable difficulty "in preventing the wire loop from being bent and pushed out of its true position when in use," and, again, that "it appeared far too fragile to keep in

anything like the necessary shape, position, and condition when in daily use underground"*; but it was hardly necessary to say that when in use underground the loop was inside a locked safety-lamp and out of all such danger. The only places conceivable for the loop to get bent out of shape—in a safety-lamp pit, at any rate—were the lamp-room and underground lamp-stations. The risk in the latter case was removed by the use of electric relighters or by a lamp fitted with an internal igniter; and, as Mr. C. J. Wilson had pointed out, the fireman himself would be likely to notice anything amiss with his lamp before he took it far from the lamp-room window, assuming the lampman himself not to have seen it.

Prof. Latham's final dictum was that the principle of the loop was "thoroughly unscientific and opposed to well-established facts,"† his reasons (if he understood them rightly) being, first, that the loop reduced the temperature of the flame and hence the cap seen was not so long as that existing over the unaltered flame, and, secondly, that the lowering of the temperature set up increased heights of fuel-caps. With regard to the latter "reason," it was hardly necessary to point out again that the tall fuel-caps which he saw in fresh air were not due to any failure of the loop, but to Prof. Latham's own fault in disregarding one of the most elementary rules of experimental investigation. Having regard to the fact that the loop method allowed of caps being observed on the full-sized flame of an ordinary safety-lamp with a minimum reduction of the flame's normal heat, the first "reason" was equally odd. If he considered the loop method unscientific because the test-flame was not quite so hot as the working-flame, what must Prof. Latham think of the ordinary mode of testing in which the flame was lowered almost to extinction? Remembering that one was here dealing, not with alcohol- or hydrogen-lamps, but with a suggestion to make an ordinary lamp into a good gas-tester without interfering with its other function of giving light, it was not uninteresting to push the argument to its logical conclusion:—If it was, as Prof. Latham stated, unscientific to tap even a part of the heat of the flame, it was evident that the most scientific method was to tap away none of it. But anything introduced into the flame, even though it was a poor conductor (such as an asbestos strip), must

* *Trans. Inst. M. E.*, 1912, vol. xliii., pages 236 and 237.

† *Ibid.*, page 239.

take away a little heat; hence, to use the ordinary, unaffected, working-flame was the most scientific method. But the cap could not be seen with such a flame; therefore, the most scientific way of gas-testing was to use a flame on which the cap could not be seen! Those not agreeing with this conclusion would be obliged to reject Prof. Latham's dictum.

If it be allowed that a locked safety-lamp with a loop inside it was capable of standing a certain amount of rough usage, it was rather surprising to find in the face of Prof. Latham's criticism, that the loop device satisfied five, and part of the sixth, of the half-dozen conditions laid down by that gentleman himself in his paper on "The Detection of Inflammable Gases in Mines," as being essential for a testing apparatus to prove of practical value.* The single condition that he (Mr. Briggs) doubted whether the loop method satisfied, was whether the indications of gas were independent of pressure and temperature. In this connexion he should like to point out the importance of Mr. C. J. Wilson's experiments.† If continued research went to establish beyond question that variations of atmospheric pressure had a considerable influence on the length of gas-caps, it would mean that flame-cap tests *per se* could no longer be taken to have a quantitative value.

As both Mr. C. J. Wilson and he had pointed out, there were other arrangements possible for fire-damp testing besides a wire loop, and he was interested to see that Mr. W. Kyle, a member of the National Association of Colliery Managers, was using successfully a perforated aluminium plate, in much the same way as the loop.‡ It might be useful to note, in case anyone experienced any difficulty in getting pure colza—though he did not think that difficulty existed—that an aluminium, silver, or nickel-wire loop made no visible fuel-cap even with the oil used at Glasgow University. The cost of silver was, of course, disadvantageous, and, in the few trials which he had made, he found aluminium to corrode rather rapidly in the flame. Nickel wire gave good results, and was very resistant.

His continued preference for the wire loop was based on the following merits which it possessed, namely: its simplicity, its very low cost, the ease with which it could be replaced when

* *Trans. Inst. M. E.*, 1906, vol. xxxi., pages 140-141.

† *Ibid.*, 1912, vol. xliii., page 232.

‡ *Iron and Coal Trades Review*, 1912, vol. lxxxiv., page 801.

necessary, and the fact that it indicated an excess of black-damp. Personally, he considered copper to be the best material, as a copper loop permitted the use of the method of intensification of the cap which the members had seen that day. The intensification was brought about by introducing 1 or 1½ per cent. of carbon tetrachloride into the oil used in the lamp, at a cost of about $\frac{1}{16}$d. per lamp per shift. The character of the flame was unaffected until the loop was moved into it, when the cap became a vivid blue, due to copper oxide, and the flame green, due to copper chloride. The cap produced could be seen without difficulty in a place lit by electric light. No clogging of the wick resulted, the colorization was permanent, and the amount of chloride added was too small to increase appreciably the fuel-cap which the oil itself gave. The latter, although invisible in ordinary circumstances and with pure oil, became apparent when the chloride was used, and this was certainly a drawback. By a little practice, however, the fuel-cap could be distinguished from a gas-cap by its colour, width, and length. The method allowed of an exceptionally high flame being used, and, with such a flame, the colour of a fuel-cap, being a faint slaty purple, contrasted fairly well with the bright blue of a gas-cap. He thought that a lamp so treated might be of service in indicating proportions of fire-damp above ¾ per cent., in a place where electric or other lights might be in use; while a skilled observer could see less than that percentage without trouble.

He (Mr. Briggs) must condole with Mr. Robinson in not being able to see the caps with the smaller percentages, but, of course, it was altogether a matter of eyesight. Mr. Robinson had stated that he was unable to detect as much as 0·85 per cent. with the loop in a certain pit, and had also very definitely affirmed that he could not see any fuel-cap. He (Mr. Briggs) had examined the oil used at the colliery in question, and had found it to give a strong fuel-cap—nearly as definite a fuel-cap, indeed, as they had seen that day when the unsuitable oil from Glasgow was being burned. He thought it highly probable, therefore, since Mr. Robinson was admittedly unable to distinguish a large fuel-cap, that he would find almost an equal difficulty in seeing a gas-cap, which although dim and sharply pointed, was sufficiently visible to moderately good eyes. It was interesting that Mr. Robinson's long experience of gas-testing with the lowered flame

enabled him to distinguish gas so readily by that method, when the larger caps given with the loop were invisible to him; and it was, he (Mr. Briggs) thought, an excellent testimonial for the Wolf lamp. In reply to a question about the latter lamp, the members had just seen a Wolf lamp burning Scottish naphtha, fitted with the loop, and would have noticed the tall gas-caps it gave. He thought Mr. Robinson would admit, however, that he was able to see caps with quite low percentages of gas when the tetrachloride colorization was used. He believed that with the latter Mr. Robinson would admit his ability to detect less than even $\frac{3}{4}$ per cent. underground. Personally, he would welcome the appointment of a committee to go into this question, because the more there were who were prepared to experiment in the pit with the loop, the better he would be pleased. He thanked Mr. Walker for the suggestion.

With regard to Mr. Milligan's observations on the standardization of oils, it was interesting that many of the States in America had laid down by law the standard and quality of oil. For example, in Kentucky, Ohio, Iowa, and the bituminous mines of Pennsylvania, there were regulations guarding against impurities in the burning oil. While he hardly went so far at present as to suggest that similar rules were necessary in this country, it did seem advisable that they should find out what was the best character of oil, where it was to be obtained, and what were the impurities most to be feared.

He agreed entirely with Mr. Sneddon that it was easier to see a cap underground than in a laboratory in which the lights were constantly being switched on and off. Because of this alternating light and darkness, the eyes were subject to no little strain during long-continued laboratory observation—a condition not apparent in the pit.

Mr. McLaren had remarked on the principle on which the loop-device worked, and what he (Mr. Briggs) had already said on Prof. Smithell's observations in part answered Mr. McLaren. The question as to how long the flame would continue non-luminous with the wire in it had, however, not yet been dealt with. The loop, as a matter of fact, was equally efficacious when red-hot as when cold, as the support conducted away all the heat that required to be taken. In one trial he had kept the same copper loop in a flame for 24 hours, in 6-hour stretches, during

the whole of which time a testing-flame was maintained. The object of the test was to get an idea as to how long it would take a loop to be destroyed by oxidation. After being in the flame for 24 hours, it was a little thin at the ends, but still was able to tap away sufficient heat to deluminate the flame.

Mr. C. L. Robinson said that, after listening to Mr. Briggs's remarks, he would like to add that he had tried to look at the device as fairly as he could. As a matter of fact, he would like it to be a success, because something of the sort was wanted. At the same time, he was not going to say that he saw a cap when he did not. On several occasions it had been his duty to say whether or not there was a complete cap on a lamp, because at that point men were to be withdrawn. Sometimes, in the districts where he had said there was a complete cap, when using colza oil, he had taken samples of the air, and the differences in the percentages only varied from 1·97 to 2·05. To vary so slightly was surely as near the limit as one could go with a lamp, and he merely mentioned the incident to show whether he could see the point of a cap or not. He thought that when burning 2 parts of colza oil mixed with 1 part of paraffin, and using Mr. Briggs's lamp, an ordinary fireman ought always to be able to detect 1 per cent. of fire-damp, and that, in his hands, the loop was useless at and below $\frac{3}{4}$ per cent.

The further discussion of the paper was adjourned.

DISCUSSION OF MR. JAMES HAMILTON'S "PRESIDENTIAL ADDRESS."*

Mr. D. M. Mowat (Coatbridge) said that they were indebted to Mr. Hamilton for bringing the question of accidents in Scottish mines before them, because it was one which was certainly of great interest to the members of the Mining Institute of Scotland. He thought that it was their duty, after having heard what Mr. Hamilton had to say, to discover why they had got so bad a name; and if they really deserved such a name, then they should endeavour to get rid of it, if at all possible. The whole of Mr. Hamilton's facts and figures were based on

* *Trans. Inst. M. E.*, 1912, vol. xliii., page 219.

statistics issued by the Home Office, and accordingly they did not lend themselves to criticism. On that account, therefore, he only intended to deal very shortly with a few aspects of the question.

In the first place, he had to point out that there had been a considerable controversy as to the proper basis on which comparisons should be made—whether they should be on output or on the number of persons employed. This was a matter which came prominently to the front a year ago during the passage of the new Mines Act through Parliament. Personally, he had to say that he agreed with Mr. Hamilton and the views that he had expressed as to comparisons being formed on the output basis. Mr. Hamilton had clearly shown, in a way that had never occurred to him (Mr. Mowat), that in taking the death-rate or number of accidents per million tons they had an absolute basis of comparison, whereas if they considered the number of persons employed they got a basis of comparison which might be more or less accurate, and as a rule was very inaccurate. A case in point was the year 1894, when the output in Scotland was reduced in consequence of a strike extending over 16 weeks. It was possible that the number of persons actually employed during the year would be the same as in the preceding years, but surely any comparison as to the number of accidents, especially when there had not been a full year's work, would be very erroneous. It should be borne in mind, moreover, that in a large part of Scotland—probably a part having one-half of the total output—there was a 5-day per week policy. Consequently, if they took that into account and made a comparison of the different districts, they arrived at results which, in his opinion, were absolutely incomparable. If a man was in the pit 6 days per week instead of 5, that individual had a greater chance of being hurt—he had, in point of fact, a fifth greater chance.

In connexion with haulage accidents, they would find that the death-rate was much higher in England than in Scotland; but there, again, they entered an atmosphere where comparison was difficult. If all the pits in England and Scotland were similar, and the mode of haulage similar, the comparison no doubt would be fair, but they knew quite well that such was not the case. It was only possible, indeed, to make a rough comparison. Perhaps on the average they in Scotland had less

extensive mechanical haulage than they had in England, but, on the other hand, Scotland had the steeper seams. In Scotland, generally speaking, they had comparatively steep measures—he referred to inclinations exceeding 1 in 8—where if a hutch ran away there was a possibility of a serious accident. In regard to shaft accidents, they would notice that Scotland was worse than the average in England. There might be reasons for that, but he could not speak on the point definitely. One reason that occurred to him was that during the bulk of the period covered by Mr. Hamilton, the number of shafts per million tons raised would be greater in Scotland than in England, because the development of the large pits in England was before that in Scotland. On the whole, however, he did not think that they could get any relief to their minds from that particular comparison, and, taking into account all the circumstances, they were not probably free from blame in Scotland.

So far as surface accidents were concerned, he thought that there was a reason why the rate was slightly higher in Scotland than in England, and that was that the former country had a greater number of plants manipulating coal and dross than the latter. In many of the great areas in England there were no washing plants at all, whereas in Scotland there were few pits where the washing process was not considered necessary. It had not altogether been a matter of choice since 1888 or 1890, because by washing a market had been got for Scottish mines which did not exist prior to that date. There was evidently now a decrease in the number of surface accidents in Scotland, and they all sincerely hoped that the total would continue to come down to some extent in the future.

With regard to accidents due to shot-firing, he thought that it was difficult to compare the two countries. It was quite easy to say that one district was better than another, but it was a matter of difficulty to say what relation they bore to each other in reference to the quantities of explosives used. One thing that had particularly struck him was that accidents which they might call disasters—say, explosions—ought hardly to be taken into account in such diagrams as Mr. Hamilton had presented to them. He thought that it was far better to eliminate anything of an extraordinary nature from their comparisons, and he had done that with regard to explosions. What he had done was

this—to take the figures in the diagram and to deduct from them the explosions, so as only to leave the totals for accidents other than explosions. In Table I. of Mr. Hamilton's Address, they would see that the total accidents in England for the 5 years beginning 1853 was 16 per million tons, and from that he had deducted the figure 4, which was shown in the explosion diagram, leaving 12 persons killed per million tons raised during that quinquennial period. For quinquennial periods since 1853 the totals, exclusive of explosions, were for England and Wales 12, 10·2, 7·8, 7, 5·5, 4·7, 4·4, 4·3, 4·1, 3·4, 3·6, and for the last 3 years 3·6. The relative figures in Scotland were 8·7, 6·3, 5·3, 4·7, 5·1, 4·3, 4, 4·1, 3·5, 3·4, 3·3, and 3·7. That comparison showed that in both countries, while there was a considerable difference between them, there was an almost continuous improvement right down to about 5 years ago. It further showed that, leaving out of account explosions, or what might be called exceptional accidents, Scotland was better than England. Then the results which Mr. Hamilton had given in regard to non-fatal accidents were really very remarkable, and in respect of these Scotland stood very well indeed. For the three years ending 1910, the figures were for Scotland 313 and for England 539. He (Mr. Mowat) undoubtedly agreed with Mr. Hamilton in the reason he suggested for that. Unquestionably, the better light that the open lamp afforded was a great factor in preventing a man from getting hurt. It was a regrettable feature that Scotland stood very well indeed. For the three years ending past 3 years than for the 5 years immediately preceding. As a matter of fact, the 5 years ending 1907 were the best on record.

One wondered how much of the increase in these later years was due to the Eight Hours Act and the hurry and bustle which it entailed. They had now to attempt to do in 8 hours or less what formerly they took 10 hours to accomplish. At the present moment they were face to face with many new regulations. They had the new Mines Act coming into force partly in July, 1912, and partly in January, 1913; they had the Insurance Act and all that it involved; they had the new Rescue and Aid Order, which probably would have been in force had their time not been so much taken up with the discussion over the minimum wage; while they had just had issued to them the new Explosives Order, which was as big almost as the Mines Act

itself. He understood that a large number of forms had to be filled up in connexion with the new Mines Act: and if a manager was expected to devote his time so much to clerical work, then he could not spend so much time underground as he had spent in the past. That was, he thought, to be regretted, because he was a firm believer in this—that the safety of the men and the pits was largely dependent on the personal supervision of the manager and the subordinate officials. Altogether, he did not think that the recent legislation and the hurry and bustle that had been put upon colliery managers during the last 6 months would make for a reduction of accidents. He was sorry to make that statement, but he made it because it was his firm conviction. During the passage of the Mines Act through Parliament in 1911 he had come into contact with mining engineers from all parts of England, and he had been perfectly astonished to hear many, who were believed to be fair-minded men, make the statement that Scotland was far worse than England in respect of accidents. By showing them abstracts from the official sources, he had been able to convince many of these persons that the impression which they held with regard to Scotland was entirely wrong. His belief was that the reason why Scotland had got so bad a name was due to the action of the Home Office in giving in their reports a special paragraph about explosions in Scotland. The result of that was that people living in Durham, Yorkshire, and South Wales had come to look upon Scotland as a dangerous region, because of this persistent reporting of ignitions of gas.

In conclusion, he thought that Mr. Hamilton was to be congratulated on his choice of a subject, and it should be their endeavour to discover where their weak points lay, and, having found them, to do what they could to get them removed or remedied.

Mr. Robert McLaren (H.M. Inspector of Mines, Airdrie) said that there was no doubt that for some reason or other Scotland had got a bad name in respect to accidents at mines. He had listened with much pleasure to Mr. Hamilton's Address, and although he had always held that the method of arriving at the death-rate was scarcely the accurate one, he was not prepared to say that the better method would be to take the death-rate on the basis of millions of tons raised. This year they had had the coal

strike, and the likelihood was that in making up the returns of persons employed for the Inspectors, no note would be taken in many cases of the 6 weeks during which the pits were idle. After all, it might be a mistake to calculate the death-rate on the basis of persons killed per million tons raised, for the reason that they did not have two pits alike. There might be a pit where a man was killed in which the men were capable of producing 3 or 4 tons a day per man, while in a neighbouring colliery employing the same number of men, but with only half the output, there might also be a fatality. A comparison in such circumstances of the persons killed per million tons raised would scarcely be fair. However, in his opinion it would be a fairer way to take the output per person killed than per person employed. He did not think that they ever got an accurate statement of the number of the men employed in the country each year, for this reason—that one pit worked 6 days per week while another only worked half the time. There was no doubt of it that Scotland stood in a very much better position than England according to the number of tons raised, but notwithstanding that, it had always had the reputation of being worse than England. It rested with the members of the Institute to do their best, and 10 years hence he hoped that the members would have a reputation which would be second to none.

Mr. G. L. Kerr (Glasgow) said that he had taken a special interest in this subject, and had done so for the past year. He quite agreed with Mr. Mowat that the fairest way was to calculate the death-rate on the amount of coal raised. For instance, they might have a colliery wholly worked by hand-labour, employing 100 men and taking out 100 tons. Two men, say, were fatally injured in that pit in the year, and that would be equal to 20 per 1,000. Supposing that another man came along, took possession of the colliery, and introduced coal-cutting machinery, up-to-date haulage, and so on. Undoubtedly with the introduction of such new machinery new dangers were added, and if the new owner reduced his men to 50 and raised the output to 150 tons a day, and there were still two lives lost in the year, that would raise the death-rate to 40 per 1,000. Which, then, of these two had the better record? He held that it was the one employing 50 men and raising a greater number of tons than the colliery with 100 men.

During the progress of the Mines Bill through Parliament in 1911, his friend Mr. Gibb and he were frequently in London in connexion with another Association. They were told when they went that Scotland was in the black books altogether, but they in turn said that they had evidence to show that Scotland had by no means the bad record she was thought to possess. He might now, for the benefit of the members of the Institute, give the figures which he had taken out on this point. He took the 5 years 1905-1909, and in that period the death-rate for explosions of fire-damp and coal-dust per million tons raised was, in Scotland, 0·234, and in England and Wales, 0·731. For falls of ground the figures were: Scotland, 1·87, and England, 2·59; for shaft accidents the figures were: Scotland, 0·41, and England and Wales, 0·34; while for miscellaneous accidents underground, haulage, etc., the percentages were: Scotland, 1·07, and England and Wales, 1·72. The totals for all classes of accidents underground per million tons raised were: Scotland, 3·61, and England and Wales, 5·40. Or for every death by explosions of fire-damp and coal-dust, Scotland raised 7·3 million tons, while England and Wales raised only 4·16. For every death by falls of ground Scotland raised 537,561 tons, and England and Wales 405,945; for every death through shaft accidents Scotland raised 2·58 millions, and England 3·51 millions; for miscellaneous accidents the tonnage raised in Scotland per death was 982,218, and in England and Wales 643,257. Taking the total of the underground accidents, for every death Scotland raised 279,164 tons, and England and Wales 205,071. That proved conclusively that, probably with one exception, Scotland was relatively in a better position than either England or Wales. He thought that on the whole the fairer way to calculate the death-rate was on the million tons basis, as the aim in all mining should be to raise the maximum quantity of mineral with the least expenditure of life.

Mr. William Walker (H.M. Inspector of Mines, Edinburgh) said that more coal was produced in Scotland by coal-cutting machinery than in any other mines-inspection district, and this was, in his opinion, why Scotland had, when compared with other districts, so high an output per person employed. It should also be remembered that there were the oil-shale mines in

Scotland, at which the output per person was larger than at a coal-mine. Scotland was not so good as other districts, so far as shaft accidents were concerned, and this was in great measure due to there being more mid-landings than in most districts, and in the majority of cases to want of light at these mid-landings. Often it only consisted of the man's own lamp fixed in his cap. He was convinced that the number of accidents would be reduced if either electric light or a fixed oil-lamp was provided to light adequately the mid-landings. The men would then be able to see which side of the shaft the cage was at, and not attempt, as they now did, to push the hutch into the opposite side.

Mr. D. M. Mowat said that he quite agreed with Mr. Walker that Scotland had more coal cut by machinery than the general average of districts. There was this to be said, however, that while machinery reduced the number of persons employed, it also increased the danger to the individual. He was sure that their object was to save lives, even although it might be only one per annum.

Mr. Sam Mavor (Glasgow) said that, in connexion with the influence of coal-cutters on accidents, he had made an investigation in regard to three groups of collieries producing an aggregate of about a million tons of machine-cut coal per annum, and had found that the ratio of accidents to output was much reduced, but the ratio of accidents to men employed was almost exactly the same as in the hand-worked districts of the same collieries. As Mr. Mowat had said, the aim must be to produce the coal at the smallest possible sacrifice of life; the investigation referred to—although not sufficiently wide in scope to warrant conclusions being based upon it—indicated that coal-cutters materially assisted towards this end, but did not reduce the hazard of the miner's employment.

The President (Mr. James Hamilton), in reply to Mr. Walker's reference to the advantage which Scotland had in the large output per man in the shale-mines, said that he had that point in his mind when he was compiling the paper, and he took the trouble to calculate the approximate average specific gravity of the minerals worked in Scotland and in England, and had

found them to be practically the same. He thought that that was quite a fair test. He agreed with what Mr. Walker had said in regard to shaft accidents, and he came to the same conclusion as he had—that a greater proportion of mid-workings off shafts raising coal in Scotland than in England probably accounted for the difference. These greatly added to the risk of shaft accidents. Possibly Mr. Mowat's explanation, that the output per shaft was greater in England than in Scotland during the earlier part of the period dealt with, was correct, but at present the annual output per mine was a little more in Scotland than in England. The reasons for preferring the ratio of output to accidents to the ratio of accidents to men employed for comparison had been so well put by Mr. Mowat and Mr. Kerr that little more need be said; but he wished to emphasize the inadequacy of the statistics supplied by the Inspectors' reports for use in a comparison on the basis of men employed. The factor of time was completely ignored therein, and, until that was remedied, it was not putting it too strongly to say that the ratio of accidents to men employed derived from these statistics was worthless as a basis of comparison of relative safety.

The discussion of the Address was closed.

The following paper, by Mr. Douglas Jackson, on "A Method of Capping Winding-ropes," was taken as read:—

A METHOD OF CAPPING WINDING-ROPES.

By DOUGLAS JACKSON.

The capping or hosing of winding-ropes has always been a subject of deep interest to colliery managers, and is now even more so, seeing that the new Mines Act stipulates that ropes must be recapped at intervals of not more than 6 months.

The ordinary methods of hosing ropes have given good results in the past, and in the majority of cases have held firm during the whole life of the rope. It is generally known, however, that the attachment of the hose to the rope is the weakest part, and would be most likely to give way before the breaking-strain of the rope is reached. With deeper pits and increased loads raised at a much higher speed, the risk of the hose slipping is undoubtedly greater.

This fact has led the writer to devise and adopt a simple method of capping, which can be applied by the colliery blacksmith, with no risk whatever of the hose or cap slipping. The tools used in preparing the rope for the cap are shown in the accompanying illustration (Figs. 1 to 6). In Fig. 1, a hose is shown fixed at one end of a piece of rope, while the other end shows the white-metal cone completed and ready to receive the hose. Each size of rope requires its own set of tools, made in proportion to the diameter. The length of the hose should be equal to twenty-two times the diameter of the rope, and the large diameter of the cone should be equal to twice the diameter of the rope.

The hose for a winding-rope is generally made of soft steel, or of Low Moor iron, with a breaking-strain of about 40 tons per square inch; but it is better to err on the safe side, and assume the breaking-strain at, say, a quarter less, or 30 tons per square inch. Fig. 2 shows the mandril, which is made of hard steel and turned in the lathe to the desired diameter and taper. This mandril is used by the blacksmith as the pattern or block on which to fit and finish the completed hose. Fig. 3 is the spike, with rings about 2 inches apart, and is turned in the lathe to the

same taper as the mandril, but is less in diameter by the thickness of two strands of the rope and rings. The rings are sawn through lengthwise, in order to give them an easy hold on the spike. The twister (Fig. 4) is used to twist the strands of the rope round the spike and rings back to their natural lay or original position. The hole in the centre is large enough to allow of the rings on the spike passing through, and the six smaller holes, spaced equally apart, receive the strands of the rope. The clamp (Fig. 5) is made in two halves, with three

TOOLS USED IN PREPARING THE ROPE FOR THE CAP.

half-glands riveted on each half, the inside head of the rivets being countersunk. The two halves, when bolted together, fit on the mandril.

To prepare the rope for hosing, the strands at the end of the rope must be sawn to an equal surface, the hose rings passed on to the rope in their order, the length of the hose measured off, and the rope lapped round for a few inches with soft wire. The rope is then fixed in the vice, the strands unfolded, and the central core cut out. Each strand is then put through one of the small holes in the twister; the spike with its rings is placed in the position of the central core of the rope, and the strands are

gradually twisted around it: when the twister reaches the top of the spike, the top ring will be a little below the end of the strands. The clamp (Fig. 5) is put on and screwed tight; this presses the strands firmly against the rings of the spike, and so holds them in position. The spike can now be turned round and withdrawn, leaving the rings inside a properly tapered cavity ready to receive the metal. A hot rod should next be put down the centre so as to heat the small ring at the bottom, and the white metal then poured in at the top. Should a leak take place at the bottom of the clamp, a touch with wet waste will stop it at once. When sufficiently cooled, the clamp should be taken off and the short ends of the strands dressed off. The finished cone will now be exactly of the same dimensions as the mandril. The hose should now be heated at the bend, the cone put into its position, and the hose closed gently down with the screw clamp (Fig. 6). The hose rings are then driven into position, and the operation is complete.

In the system here described, the cone is well formed and solid, so that there can be no corrosion of the wires, and, in addition, the strands of the rope have their natural twist.

The writer had six tests made with short lengths of rope, and not one of them broke under the breaking-strain given in the rope-makers' tables.

Another test was made with a short length of rope. One end was hosed by the rope-maker, the other in the manner already described. The result was that the rope broke inside the rope-maker's hose with a strain of 75 tons, or 78 per cent. of the breaking-strain of the rope, which was stated in the maker's tables as 96 tons. After examination, the cause of the breakage was seen to be that the rope-maker in hosing his end of the rope had adopted the method of turning back the strands over an iron ferrule, and interweaving the ends into the rope again. The taper made was therefore imperfect, and no two strands were subjected to the same strain.

Richards's self-tinning plastic white metal was used for the hosing of all the ropes tested, its melting-point being as low as 500° Fahr., and its contraction in cooling almost *nil.*

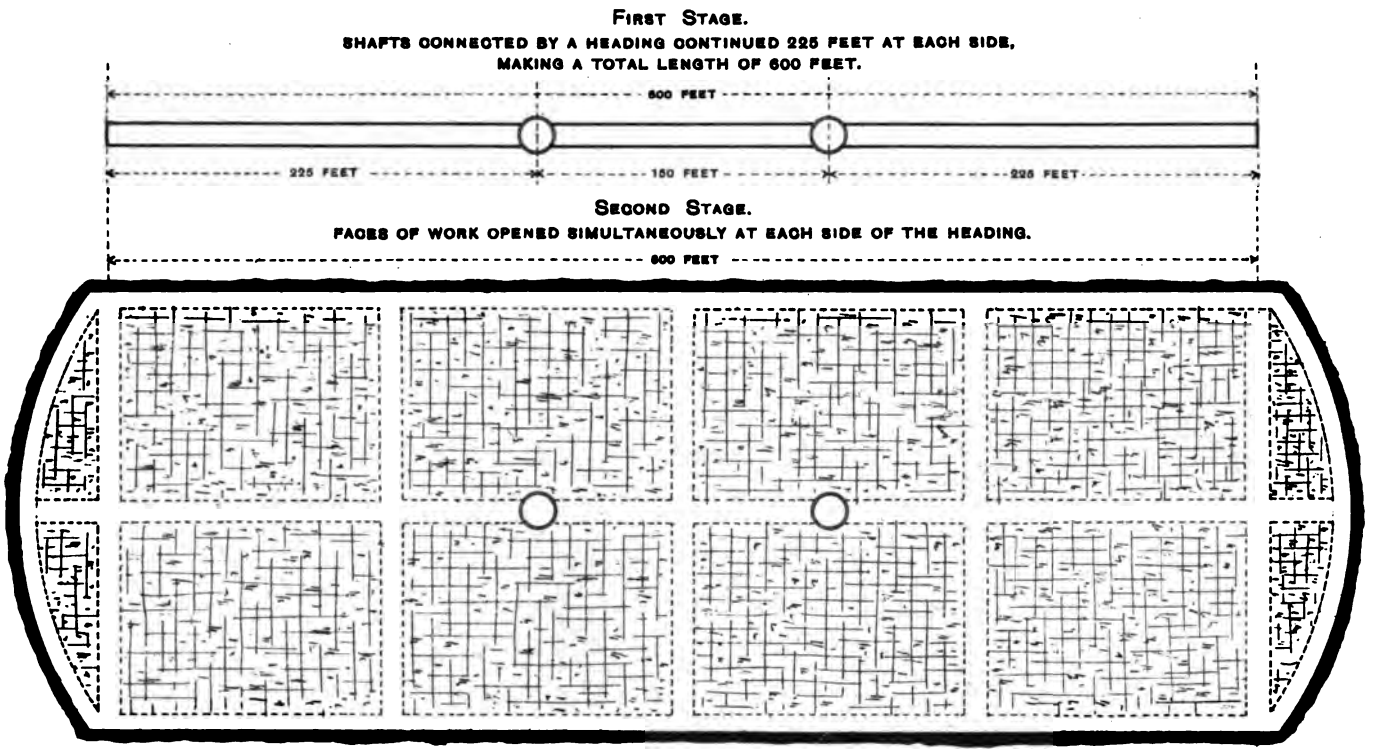
THE MINING INSTITUTE OF SCOTLAND.

PLEASURE EXCURSION TO CAMPBELTOWN,

JUNE 29TH, 1912.

Members and their friends, numbering about 150, were conveyed from Glasgow by train to Wemyss Bay, and thence by the turbine steamer, "Queen Alexandra," to Campbeltown, where they had an opportunity of travelling on the Campbeltown and Machrihanish Light Railway to Machrihanish Bay and the Campbeltown coal-field.

The following "Notes on the Campbeltown and Machrihanish Light Railway and the Campbeltown Coal-field," by Mr. T. Lindsay Galloway, were distributed for the information of the members of the party:—


FIRST STAGE.
SHAFTS CONNECTED BY A HEADING CONTINUED 225 FEET AT EACH SIDE,
MAKING A TOTAL LENGTH OF 600 FEET.
600 FEET
225 FEET
150 FEET
225 FEET
SECOND STAGE.
FACES OF WORK OPENED SIMULTANEOUSLY AT EACH SIDE OF THE HEADING.
600 FEET

Scale, 100 Feet to 1 Inch.

And.w Reid & Comp.y L.td Newcastle upon Tyne.

NOTES ON THE CAMPBELTOWN AND MACHRIHANISH LIGHT RAILWAY AND THE CAMPBELTOWN COAL-FIELD.

By T. LINDSAY GALLOWAY.

The Campbeltown and Machrihanish Light Railway is a narrow-gauge line, about 6 miles in length, extending right across the peninsula of Kintyre. It was originally constructed for the conveyance of coal from Argyll Colliery to Campbeltown, but was reconstructed, extended, and equipped for passenger traffic in 1906. The gauge is 2 feet 3 inches, and the line is the only example of a narrow-gauge public railway in Scotland. The permanent-way consists of flat-bottomed steel rails of 50 pounds per yard. The line is single, with sidings near Campbeltown, and branches to the colliery, harbour, and coal-depôt. There is one passing place half way. The traffic is regulated by the electric-tablet system—a method which admits of great elasticity of working, combined with safety.

With regard to rolling-stock, the passenger carriages are 45 feet long by 7 feet in width, and can each accommodate 64 passengers. They are provided with central buffers, and are fitted with continuous vacuum-brakes. The locomotives have outside cylinders 11½ inches in diameter by 18 inches stroke, and are fitted with Walschert valve-gear, and steam-brakes. Their weight is 22 tons. The coal-wagons are of the box type, and carry from 3½ to 4½ tons.

The Campbeltown coal-field lies to the west of Campbeltown, and extends below the sea at Machrihanish Bay. Its geological horizon was for a long time uncertain, but fossils identical with those which are characteristic of the Index Limestone have been found in the strata overlying the coals, which therefore belong to the Lower Carboniferous Series.

The existence of coal-bearing strata has been proved to a depth of 1,000 feet towards the northern side of the field. The present shafts, which are sunk on the southern side, are only 240

feet deep, but the workings extend more than 1,000 yards to the dip, and have reached a depth of 800 feet below the surface. The quantity of water which has to be dealt with in proportion to the output is considerable; and this was one of the first collieries in Scotland at which three-phase electric current and high-lift turbine-pumps were introduced.

The earliest reference to coal in Kintyre occurs in the year 1498, when James IV. sent "ane cole man to pass in Kintyre to vesy gif colis may be wonnye thare," and the sum of eighteen shillings was paid to a Dumbarton collier to make working tools and to proceed into Kintyre.

Coal has been worked in Kintyre for 150 years. The old village of Salt Pans, by the seaside at Machrihanish, no doubt derives its name from the fact that the coal found near the shore was here used for the manufacture of salt by the evaporation of sea-water. There must have been a considerable traffic in coal in the middle of the eighteenth century, as a canal was constructed about the year 1774 for the conveyance of the mineral to Campbeltown; and it is interesting to recall the circumstance that the original survey was made by James Watt.

THE SOUTH STAFFORDSHIRE AND WARWICKSHIRE INSTITUTE OF MINING ENGINEERS.

GENERAL MEETING,

HELD AT THE COUNCIL HOUSE, WALSALL, JUNE 17TH, 1912.

PROF. JOHN CADMAN, VICE-PRESIDENT, IN THE CHAIR.

The following gentlemen, having been approved by the Council, were elected:—

ASSOCIATE MEMBER—

Mr. W. T. DINNEEN, Ipoh, Perak, Federated Malay States.

ASSOCIATE—

Mr. F. G. CLARKE, Fosseway, Lichfield.

The SECRETARY read the minutes of the last General and Council Meetings, which were confirmed.

Messrs. T. J. Davis and W. H. Whitehouse were appointed Auditors and Messrs. John Hughes and F. G. Meachem Scrutineers for the coming year.

Mr. W. CHARLTON read the following paper on "Modern Ventilating Machinery," which was illustrated with lantern-slides:—

MODERN VENTILATING MACHINES.

By W. CHARLTON.

Introduction.—When the author was asked to contribute a paper on a subject of interest and profit to the members, he found that there had been little or no reference to the subject of mechanical ventilators since the question was so ably treated by the late Mr. M. Walton Brown, in his report on "Mechanical Ventilators."* Mr. Brown stated in a very lucid manner the generally accepted theories of Mr. D. Murgue on the action of centrifugal ventilators, and later the subject was ably dealt with in a graphic manner by Mr. H. W. G. Halbaum.† The author does not propose to traverse that ground again, but, with the aid of information supplied both by makers and colliery companies, to point out briefly some of the chief features of machines now being installed for colliery ventilation.

Changes in Construction of Mechanical Ventilators.—Quite a revolution in construction has been brought about in colliery fans, the changes introduced being chiefly as follows:—

(1) A great reduction in the diameter of fans. Many of the old machines were 30 and 40 feet in diameter, but machines of little more than double that number of inches are now circulating even larger volumes of air than the old and larger machines circulated. This reduction in size has had its effect on the size of the shafts required to carry the fans and on the costs of foundations.

(2) The method of driving the fans. Most of the old machines of the Guibal and Waddle type were driven direct by slow-moving badly designed horizontal engines. The modern machines are in most cases driven direct by vertical high-speed engines designed for the smallest possible steam-consumption; whilst in some they are driven by electric motors coupled directly

* *Trans. Inst. M. E.*, 1899, vol. xvii., page 462.

† "The Theory of the Equivalent Orifice treated Graphically," by H. W. G. Halbaum, *ibid.*, 1900, vol. xx., page 494.

to the fan-shaft. Where an alteration has to be made between the revolutions of the motor or engine and the fan-shaft, the form of drive found most effective is that by ropes. Whilst travelling recently in the South Wales coal-field, a point with regard to rope-drives and the provision of duplicate drives came to the writer's notice. In this case a Sirocco fan had fitted to each end of its shaft a rope-pulley. Two motors were provided as alternative drives, and the custom was to run them alternately for a month at a time. Considerable delay and a period of slow running occurred at each turnover from one motor to the other. This was due to the ropes not finding their seatings in their grooves until after a period of running.

To avoid this defect, another plant erected by the same engineers had clutches inserted, one on each side between the rope-pulley and the fan. When a change is now made, it is not necessary to take the ropes off one pair of pulleys and replace those on the other pair of pulleys; it is only necessary to take out one clutch and insert the other.

(3) In the internal construction of modern fans, in which perhaps the greatest changes have taken place. In the old types the blades extended from the shaft-boss to the circumference; in the new types there are no blades in the centre—only very short ones arranged around the circumference. In the old types various shapes of blades were adopted—some straight and inclined backwards, as in the Guibal. In most of the other types the blades were curved backwards, so as to be almost tangential with the circumference where they joined it, the general idea being to provide an easy passage for the air through the fan and into the external atmosphere. One type of blade adopted in modern machines is short and curved, with its concave surface facing the direction of rotation, forming, so to speak, a scoop.

Messrs. Bumstead and Chandler have slightly compromised between the old and new types. The first parts of their blades are scoops, the outer portions being curved backwards, with the avowed object of giving easy delivery; and they claim for this construction a higher mechanical efficiency than is obtained with scoop-blades.

Another change is in the number of blades. In the old types, eight and ten blades were considered sufficient; in the newer types, the number sometimes exceeds sixty. The reason given for

this change is that in the old types the areas between the blades increased from the centre to the circumference, forming dead spaces, which gave rise to eddying currents, and considerably hampered the free passage of the air. In the newer types the large number of short blades cut the air into as many small streams, the passage of which is very short and not subject to the hindrances experienced in the old types.

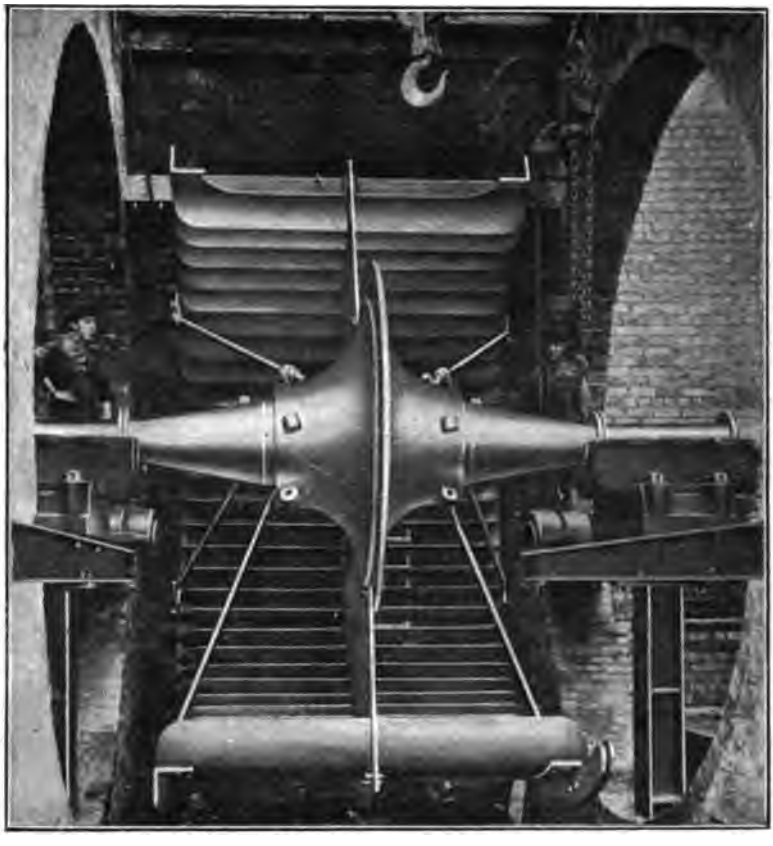


FIG. 12.—SIROCCO MINE FAN.

These points in construction are brought out in a short consideration of three types of modern fans:—

Fig. 1 (Plate X.) and Fig. 12 in the text show a Sirocco fan, which may be either of the single or of the double inlet type. There are sixty-four blades arranged round the circumference.

The end of the shaft of the single-inlet fan carries a cone; in a double-inlet fan there is a central diaphragm dividing the fan into two parts; and on each side of the diaphragm is a cone similar to that on the end of the shaft of the single-inlet fan. It will be noted that the fan delivers into a casing of gradually increasing capacity, terminating in an évasée chimney. The rim of the fan is braced to the central shaft by a number of tie-rods.

Fig. 2 (Plate X.) and Fig. 13 in the text are illustrations of a Chandler fan, in nearly all respects similar in construction to a Sirocco, with the exception that the extremities of the blades, as previously stated, are curved backwards to give easy delivery

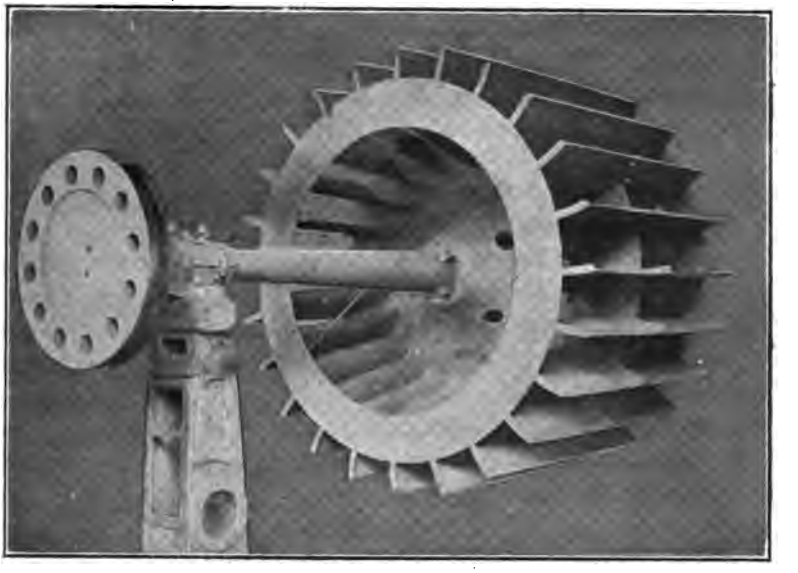


FIG. 13.—CHANDLER MINE FAN.

of the air. The volute chamber into which the air is delivered is larger even than in the case of the Sirocco, and terminates likewise in an évasée chimney.

Fig. 3 (Plate X.) shows the Barclay fan, in which very similar principles of construction are adopted.

It may be profitable to enquire briefly into the effects of these changes in internal construction on the general efficiency of a ventilating machine. It is generally claimed that a primary effect of the cutting out of blades from the centre of the fan has the effect of reducing internal resistance.

To bring out this point, a restatement of the action of a centrifugal fan may be allowed. A fan acts by bringing about a depression or reduction in pressure at its centre. This depression is expressed by the formula—$H = \frac{u^2}{g}$, in which H = the depression, expressed in feet of air-column; u = the periphery speed of the fan, in feet per second; g = the usual gravitation unit of 32·2. This depression may be expressed in the more familiar form of inches of water-gauge, as follows:—$WG = \frac{12u^2}{g}\frac{d}{D}$, in which $\frac{d}{D} = \frac{\text{density of air}}{\text{density of water}} = \text{say, } \frac{1{\cdot}2}{1{,}000}$. This statement is for a perfect fan running under ideal conditions. As no such ideal fan and conditions exist, the formula has to be modified by the introduction of a coefficient k, which may vary in value for each individual fan.

$$\therefore WG = k\frac{12u^2}{g}\frac{d}{D}.$$

It will, however, be much more convenient to express the effect produced by a fan as H, with the understanding that it may be expressed either in feet of air-column or in inches of water-gauge.

The depression initially set up by a fan is used up in overcoming the resistance of the mine, indicated by h, and the internal resistance of the fan itself, the value of which is shown by h_o; therefore $H = h + h_o$. The evident object of fan-makers must be to keep down h_o—that is, the internal resistance of the fan; or, to adopt Mr. Murgue's simile, to enlarge the "orifice of passage of the fan."

The manometric efficiency of a fan is expressed by the ratio of the initial and theoretical depressions; an approximate efficiency may be expressed by the ratio of the effective and theoretical depressions; although it will be evident that the more nearly the effective depression approximates to the initial, the greater will be the proportion of the actual energy of the fan utilized in effective ventilation. Any modification in construction that realizes this must be welcomed as an improvement.

Again, in the old types of fan the size of the inlet was only a half to a third of the diameter of the fan, whereas in the modern makes the size of the inlet is equal, or nearly so, to the external diameter, the whole effect being to give an unimpeded entry of air into the centre of the fan.

If the cutting away of internal blades and the enlargement of the inlet be advantageous, how unscientific must be that idea incorporated into some recently made Capell fans, where the edges of the interior blades are turned up, with the intention of making the blade into a scoop and increasing the depression, but with the practical result of seriously throttling the inlet to the fan.

A comparison of the shape of blades in old and new types is interesting. In the former, as previously mentioned, two general types of blades are used, namely (1) straight, but inclined backwards as in the Guibal; and (2) blades curving backwards from the direction of rotation.

In the new fans the scoop-blade is adopted, with the exception (as before noted) that in the Chandler fan the extremities of the blades are curved backwards from the direction of rotation. The claim of the makers is that this form of blade has a more positive effect in bringing about depression or water-gauge.

An experience of the writer in South Wales somewhat confirms this view. In a certain dusty mine, ventilated by a Sirocco fan, it was found after a short period of running that there was a sensible drop in the water-gauge. As the speed of the fan had not altered, this was difficult to account for, until the fan was stopped and examined. It was then found that the cavities of the fan-blades had become filled with dust, making the blades straight instead of curved. The remedy has been found in the provision of a duplicate fan, and a modification in the casing—by which one fan after a period of running can be taken out and replaced by the other whilst the blades of the former are cleaned from the adhering dust.

It will be noted that in the three examples of modern fans which have been mentioned, very similar designs of discharge-chamber and chimney are adopted. These are not, however, new ideas. The volute discharge-chamber was adopted in the old Schiele fan, and the évasée chimney was first introduced by Guibal.

Summing up the modifications in construction of modern fans as compared with the old ones, the writer recently in conversation was asked by a fan-maker: "What part of a fan is taken into consideration in calculations as to its effect." The writer replied: "The velocity of the blade-tips." Then said the fan-

maker: "Why not make it all tips"? That appears to be an outstanding idea in the construction of modern fans—they are nearly "all tips."

In Mr. M. Walton Brown's report on mechanical ventilators, the manometric efficiency for the Guibal fan was a little over 0·6, for the Schiele fan it ranged between 0·47 and 0·55, and for the Waddle fan it ranged between 0·44 and 0·49.

The figures contained in the accompanying table have been supplied by Messrs. Davidson & Company, Limited, the makers of the Sirocco fan. The columns for initial depression and manometric effect have been added by the writer. The five cases quoted refer to double-inlet fans.

SUMMARY OF TESTS ON SIROCCO DOUBLE-INLET FANS.

No. of Test.	Diameter, in inches.	Revolutions, per minute.	Volume of air, in cubic feet per minute.	Calculated Initial Depression (Water-gauge).	Observed Water-gauge in Fan-drift.	Manometric Efficiency.	Horse-power, in air.	Brake-horse-power on Fan-shaft.	Fan efficiency.
				Inches.	Inches.				Per cent.
1	77	284	120,600	4·56	4·03	0·88	76·6	100·6	76·0
2	98	184	220,000	3·09	2·75	0·88	...	...	...
3	140	183	340,030	5·62	6·01	1·06	323·23	390 0	82·87
4	161	167	493,850	6·88	6·16	0·88	479·33	553·0	86·67
5	161	203	598,000	10·32	9·07	0·88	854·00	1,000·0	85·40

Seeing the remarkably concordant results of tests Nos. 1, 2, 4, and 5, it is suggested that there is some error or circumstance unknown to the writer to account for case 3.

If the figures supplied by Messrs. Davidson & Company are correct, the Sirocco fan gives a manometric effect of 0·8 to 0·9, so that on comparison the modern makes use up a comparatively small amount of their own energy in overcoming internal resistance.

The foregoing figures are submitted with reservation, as the methods adopted in making the observations are not stated. At the same time, the writer suggests that they are sufficiently remarkable to induce those firms that may have installed modern fans of the type described in this paper to have tests made such as may confirm or modify the results put forward by Messrs. Davidson & Company.

Reversal of the Air-current.—One of the clauses of the new Coal Mines Act of 1911 requires that, where a mechanical contrivance is used for ventilation, provision shall be made to reverse the ventilation. There is no doubt that the recent cases of underground fires in the neighbourhood of downcast-shaft bottoms and in intakes, and the consequent contamination of the whole air-circuit by smoke and foul gases, thus cutting off access to the mine, are responsible for this new departure; and at most mines where the rule applies, plans are being considered for the enforcement of this provision. Several fan-makers have been good enough to submit their proposals to the writer, and a selection has been made by him. The plans generally follow one or other of two broad principles, namely:—

(1) The fan to be so arranged that it can either exhaust from, or blow into, what is normally the upcast shaft.

(2) The drifts to be so arranged that the fan may exhaust either from the upcast shaft or from the downcast shaft, and in the latter case the top of the normal upcast to be opened to the atmosphere, whilst a covering will be arranged for the normal downcast to cut off the connexion with the external atmosphere.

A modification of the second plan has been adopted. A stand-by fan is connected to the downcast pit, and, in case a reversal is required, all that will be necessary will be to stop the fan exhausting from the upcast shaft, open the fan-drift doors, start the stand-by fan, and cover the downcast pit-top.

Methods of Reversing.—Figs. 4 and 5 (Plate X.) show one plan proposed by Messrs. Bumstead & Chandler. The elevation and plan are of a double-inlet Chandler fan. It will be noted that the évasée chimney is placed in a somewhat different position from the usual one. Here it is erected on the fan-drift side of the fan, instead of on the opposite side. It will be noted in Fig. 4 (Plate X.) that the lower portion of the chimney-case is hinged in such a way that, by drawing it up, the outlet is closed and a fresh opening made into the fan-drift, through which fresh air is blown into the normal upcast pit. This hinged door is counterbalanced by weights hanging outside the fan-casing, in order to facilitate its manipulation. At the same time, by opening two iron doors, situated on the outside of each of the fan-inlets respectively, the fan centre is put into communication with the external atmosphere.

Figs. 6 and 7 (Plate X.) show the plans suggested by Messrs. Davidson & Company, the proprietors of the Sirocco design. Here the V partition that divides the fan-race into two portions and conducts the air in two streams, one to each inlet of the fan, consists of two doors, which when opened would cut off the access of air from the upcast into the fan-inlets, and make a fresh opening from a duct over the top of the fan-casing, by which air can be blown into the upcast pit. This duct enters the fan-chimney, and when reversal is required a shutter, which normally closes the mouth of this duct, is raised and simultaneously closes the outlet and opens the duct. The two inlet-chambers to the fan-centre are extended some little distance on each side of the fan, and each contains two doors. The opening of these puts the fan-centre into communication with the external atmosphere.

Figs. 8 and 9 (Plate X.) show the arrangements with a Barclay double-inlet fan. As in the Chandler arrangement, a portion of the bottom of the fan-chimney is so hinged as to open outwards into the fan-drift. A second shutter is required to close the chimney. Again, two doors form the V dividing the fan-race. By the manipulation of these, communication from the upcast to the fan-inlets can be cut off, and an opening provided for air from the new delivery orifice of the fan to the upcast shaft.

Figs. 10 and 11 (Plate X.) show an arrangement suggested by Messrs. Davidson & Company in a specific case to enable the fan to exhaust either from the upcast or from the downcast shaft.

Conclusions.—It is not the intention of the writer to discuss the relative merits or demerits of these plans. No doubt with experience they may be modified or improved upon. There may arise, however, some discussion as to which method in principle will be the more efficient, namely, blowing into the upcast or exhausting from the downcast shaft. In the writer's opinion, the term "efficiency" in this connexion has quite a different significance from that commonly attached to the word when used in association with mine ventilation. In the contingency contemplated by the provision of this apparatus, it may be sufficient to reverse the direction of the air-current, and so

FIGS. 4 AND 5.—CHANDLER DOUBLE-INLET REVERSIBLE MINE FAN.

FIG. 1.—BAR

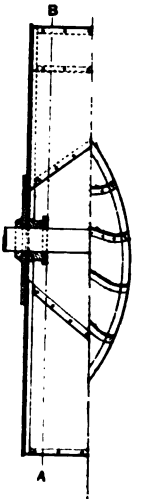


FIG. 4.—SIDE ELEVATION.

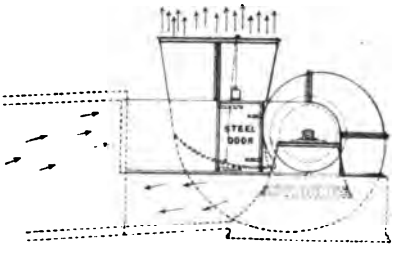


FIG. 5.—PLAN.

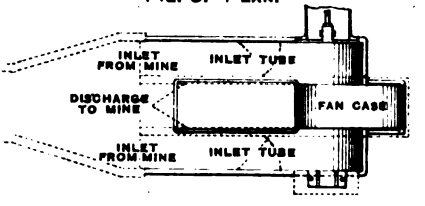


FIG 10 AND 11.—SIROCCO DOUBLE-INLET REVERSIBLE MINE FAN, SHOWING AIR-CURRENT REVERSING ARRANGEMENT.

FIG. 10.—SECTION THROUGH LINE AB OF FIG. 11.

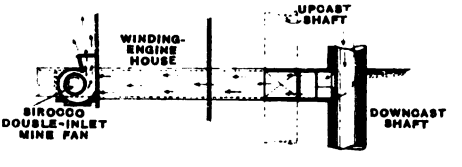
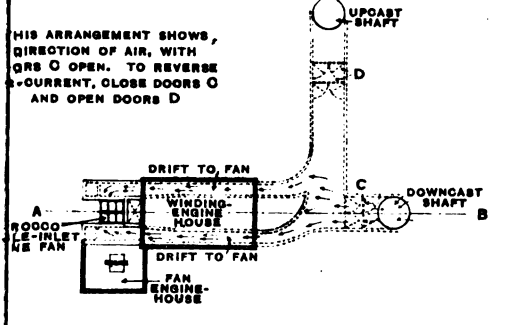


FIG. 11.—PLAN.



prevent the workings from becoming fouled and inaccessible; for, unless special arrangements are made underground to prevent it, the ventilation will be short-circuited to the shortest cut from shaft to shaft.

The point as to whether it is worth while to make provision to prevent this from occurring may be a good subject for debate. In case it is considered desirable, not only to reverse the direction of the air-current between shaft and shaft, but also to establish a fairly considerable ventilation of roads beyond, necessitating a fairly considerable volume of air, then the method of exhausting from the downcast shaft seems the one most likely to fulfil these conditions. The conditions of working of the fan remain as before, the only difference being that it exhausts from one shaft instead of from the other; and against natural ventilation. Even in that case the same volume of air could not be expected under reversal conditions as under normal conditions.

The CHAIRMAN (Prof. John Cadman) said that as mining engineers were looking up the subject of mine ventilation at the present time, and, as they were all fairly *au fait* with some of the points raised by Mr. Charlton, they ought to have a very interesting discussion, and he hoped that there would be a frank expression of opinion.

Mr. H. C. PEAKE (Walsall) said that he was unable to agree with some of the points that had been raised, but he scarcely felt competent to say much on the subject, because he had not had an opportunity of reading the paper. Personally, he was not very partial to fans, because he believed that fans were designed by people who wanted to keep their air-currents high in the mine. But many of the difficulties of which they had heard recently with respect to coal-dust were now passing away. From Mr. Charlton's point of view, the paper was an admirable one, and it seemed clear that, if they were to have fans, they must have them so arranged that the air-current could be reversed. Fans might be necessary in some cases, but he believed that if not altogether death-traps, on the whole their mines were very much better without them. He had great pleasure in moving a

hearty vote of thanks to Mr. Charlton for his paper, which must have cost a good deal of time and labour.

Mr. Noel Chandler (Hednesford) had great pleasure in seconding the motion. There were some points that he should have liked to have considered rather more fully, but as he had only read the paper just before coming to the meeting, he was hardly able to deal with them as they deserved.

There was a statement in the paper that the Chandler fan was "in nearly all respects similar in construction to the Sirocco, with the exception that the extremities of the blades are curved backwards to give easy delivery to the air." He (Mr. Chandler) had carried out a large number of experiments with various shapes of blades, and about 20 years ago had put down a fan at the Cossall Colliery, Derbyshire. He believed that that was long before the Sirocco fan was thought of, and from that fan a consulting engineer had got a mechanical efficiency of 82 per cent. With regard to the figures given embodying the summary of tests on the Sirocco double-inlet fans, he thought that they must take those figures with a grain of salt.

Mr. Charlton had dealt with the question of the tips of the blades, and referring to some recently-made Capell fans, the edges of the interior blades of which were turned up, he had stated that this was "with the idea of making the blade into a scoop and increasing the depression, but with the practical result of seriously throttling the inlet to the fan." For many years past, Messrs. Bumstead & Chandler, Limited, had been making blades to scoop up the air from the inlet and deliver it to the volute smoothly, the blade slightly reclining backwards from the radial line; and they had carried out a large number of experiments with the view of finding out the best way to secure high water-gauges with less loss of mechanical efficiency. That firm had always followed the plan of scooping up the air at the inlet. The slight S shape was with the object of getting the air smoothly into the évasée of the fan, and they had found that by scooping up the air in the manner that they had adopted, they gained in efficiency, but there was a loss of efficiency if the tip of the blade was advanced. That was why they had for so many years retained their present system.

Replying to a question by Mr. S. L. Thacker, as to whether,

in speaking of higher water-gauge and mechanical efficiency, he had referred to the curving of the blades forward at the point of entry or delivery—Mr. Chandler said that he was speaking of the effect at the tip of the blade and the water-gauge at the inlet chamber. A higher efficiency was obtained by turning them backward, and the mechanical efficiency was improved, because they got less difference between the horsepower in the air and the brake-horsepower of the engine or motor.

The author had mentioned a certain fan in South Wales as "becoming quickly choked up with dust, the effect of which was to make the blade straight or radial instead of curved." That seemed to prove that the air did not follow easily the curve of the blade.

Mr. S. L. Thacker (Walsall) said that he had much pleasure in bearing testimony to the value of the paper and in supporting the vote of thanks. He was afraid that his acquaintance with fan formulæ had become a little rusty since he had had the benefit of Mr. Charlton's tuition on the subject. Previous writers had remarked on the analogy between a fan and an electrical machine. Both of them produced an initial difference of pressure: in the one case a difference of air-pressure measured in feet of air-column, and in the other a difference of electrical potential measured in volts. They both produced a volume—one of air, the other of current; and they were both subject to losses, the amount of which increased with the internal resistance and the volume of air or current passed.

That very point of internal resistance was the important point upon which the paper concentrated attention. It seemed to him (the speaker) that recent practice in fan-design was in the right direction. The difference of pressure or depression produced by a fan depended upon the centrifugal force in the air set up by the circumferential speed of the fan, and the object of the designer was to set in motion an annulus of air at the fan-periphery at the required speed. Provided that he could do this by a good mechanical device, it mattered little what became of the blades between the annulus and the fan-centre. It would seem that the more they covered up the fan-inlet with blades, the more they added to the resistance met with by the air in passing through the fan, and on those grounds he thought that the success

of the fan with short blades was clearly explained, because it seemed that multiplying the number of blades gave the necessary velocity to the narrow annulus of air at the fan circumference and their short length reduced its internal resistance.

Reference had been made to the Report of the Mechanical Ventilators Committee of the North of England and Midland Institutes, edited by the late Mr. M. Walton Brown. He (Mr. Thacker) thought that the time was now ripe for a further report on mechanical ventilation. A vast amount of valuable information and data was brought forward by that investigation, but in his judgment it went somewhat on wrong lines, because it was limited to tests of fans of different types on the same mine. He did not think that such a limitation should have obtained; and, further, the method adopted involved the calculation of the equivalent orifices of the mines from the data obtained by the tests of the fans themselves. He was of opinion that before satisfactory results could be obtained, it was necessary to standardize the resistance. Every engineer knew that before it was possible to carry out experiments upon any mechanical appliance, the first necessity was to standardize the methods of measurement and the appliances that were used.

He suggested that before further tests of mine fans were carried out, a committee of The Institution of Mining Engineers, or of the Institution of Civil Engineers, or of both acting jointly, should standardize artificial equivalent orifices for different sizes of fans, and then carry out comparative tests upon such recognized standards. They would then have reliable data, reliable methods of testing, and truly comparative results. It was clear that satisfactory comparative tests of fan-efficiencies could not be obtained with varying volumes of air, varying water-gauges, and under varying mine conditions.

Referring to the question of the reversal of the air-current, it was very debatable as to what was the best method of reversal. In the case of many existing mines the second method mentioned in the paper would be impracticable, as it was not always possible to connect the fan by drifts with either shaft. But he thought that it was the method which would have the greater practical utility, and would be adopted in the case of new mines, because one of the principal dangers which a reversal was designed to meet was the case of a fire at the bottom of the down-

cast shaft or in the main intake, and he was doubtful whether a fan blowing down the upcast would be as efficacious in preventing the fumes from reaching the workings as a fan exhausting from the downcast.

Mr. LAURENCE HOLLAND (Hamstead Colliery) said that although it was necessary to consider the theoretical qualifications for a fan, they must not lose sight of what the practical qualifications were. In the Sirocco fan, a very high manometric efficiency was aimed at, but the case was different with the Chandler fan. In the latter machine air was easily delivered, but in the former there was great strain on the blade-tips. From what he had seen of the Sirocco fan and the Chandler fan, he did not think that there was any comparison in the life of the two machines, and that was a very important point which the colliery manager had to consider. An equally important point, dealt with by Mr. Charlton, was the reversal of the air. To be able to reverse the air in a mine was most useful and desirable; but it was a very difficult position for anyone to be in to have to decide whether or not the air should be reversed, and he sincerely hoped that he would never find himself compelled to decide such a matter. If there were men working down the pit endeavouring to extinguish fires in the workings, and the air was reversed, there was a very great risk of losing those men's lives. If, when they had a fan capable of reversing the air, the air was not reversed in the event of a fire in the pit, and there was loss of life, then in that case they would be sure to be blamed by the Government. It was indeed a very knotty question to decide what they were to do, and easy to be wise after the event.

Another point dealt with was the form of drive, and Mr. Charlton had stated that the most effective form that he had found was that of ropes; but he would like to ask whether he did not think that a direct drive would be better, because in that case they would get practically no loss. With a high-speed engine coupled up to a high-speed fan, he thought that they got very much better results than with a rope or a belt-drive. If ropes were used, they might have too many, which meant extra friction; and if they had too few, some of them were liable to slip, with consequent loss of efficiency. Ropes were all very well while

they were new, but he had often seen some of them either sagging or tight, and in neither case was the result satisfactory.

He had very much pleasure in supporting the resolution of thanks to Mr. Charlton, who had done a vast amount of work in going carefully and closely into the subject.

Mr. J. W. McTrusty (Nuneaton) said that a rather interesting point arose in connexion with the theoretical depression which Mr. Charlton had indicated by the formula $H = \frac{u^2}{g}$. It was of interest to note that in Murgue's investigations into the pressure produced by a fan there was a second term involving the cosine of the angle which the blades made with the periphery. In order to get rid of this term, he considered this angle to be 90 degrees, making the cosine factor zero and leaving the expression as used by Mr. Charlton. It would be noted that when the blade curved forward the cosine was still negative. Hence this double negative gave a plus quantity, making the value of H greater than the u^2 divided by g. From figures which had been mentioned in connexion with the Sirocco fan, it would appear that in this case the theoretical depression should be something like 1·5 times $\frac{u^2}{g}$. Consequently, the table of manometric efficiencies given by Mr. Charlton should throughout be multiplied by two thirds. It would appear that the term "manometric efficiency" required a better definition, as one factor (h) used by Mr. Charlton referred to the resistance of the mine and the other (H) referred to an arbitrary theoretical depression. Hence it was difficult to see how that expression could have reference to the efficiency of the fan. It was clear that in order to estimate the efficiency of a fan, one must have both quantity and pressure.

With regard to the reversal of the air, the only point that he wished to mention was the principle involved by reversal either by blowing or by exhaustion. In his opinion, reversal should be effected by blowing, and not by exhaustion, inasmuch as by the former method pressure was increased throughout the pit, making it certain that bodies of gas could not be moved from one side of the pit to the other on reversal.

Mr. F. B. Clark (Aldridge, Walsall) said that, with regard

to manometric efficiency, he had recently tested two fans in the North of England, and had obtained a manometric efficiency of over 100 in both cases. He thought these results rather strange, and when he discussed the question with those on the spot, they had given the same answer as the gentleman who had just spoken, namely, that in most modern fans the velocity of the air leaving the fan was greater than the velocity of the tips of the fan.

With regard to the method of driving the fan, if a modern fan was coupled to the engine, the engine must be more or less of the high-speed type and generally vertical. There were many who claimed that the horizontal slow-speed engine was less likely to break down than a high-speed engine, and that therefore a slow-speed engine driving the fan by a rope-pulley was better than a high-speed engine. But nowadays high-speed engines were almost, if not quite, as reliable as slow-speed engines, so that, having regard to the power lost in rope-transmission and the extra space required, there appeared very little to choose between the two methods. If anything, the direct-coupled method, however, seemed the most suitable. The uneven torque obtained from the direct coupling was considered by some people to be more likely to damage the fan, but such an idea appeared to be more theoretical than practical.

With regard to the electric driving, the torque of an electric motor was so even that, unless speed reduction was required, there was obviously no economy in using a rope-pulley drive, since power must be lost in transmission by such practice. A direct-current motor could have its speed economically regulated. In other words, if the fan was only required to do half the work and it was driven by a direct-current motor, then the speed of the direct-current motor could be regulated without using up all the superfluous power in resistance. A direct-current motor, in fact, took current from the mains in proportion to the work that it gave out. But an ordinary alternating-current motor used the full supply of current no matter what work was required of the fan, all superfluous power being dissipated in resistances. Bearing this in mind, and having regard to the large number of collieries that only generated alternating current for power purposes, it did not seem economical to put in an alternating-current motor to drive the fan when a new colliery was being

opened out, seeing that it might be 3 or 4 years before the full output of the fan would be required. Indeed, if the boiler-gallery was situated close to the fan, there was no economy in driving the fan electrically, the only gain being an improvement of the load-factor of the electrical plant, the importance of which was often exaggerated by electrical engineers. When the fan was some distance from the boiler-gallery, then electricity was certainly to be recommended. It might be of interest to the members to know that an arrangement had been recently introduced by Messrs. Brown, Boveri, & Company, Limited, which enabled an alternating-current motor to obtain economical speed variation. This was done by the introduction of a commutator-motor connected in cascade with an induction-motor, which took in electrical energy from the slip-rings of the latter and transformed it into mechanical energy, so that the power required for regulating the speed was regained. But the arrangement was somewhat costly and complicated, and, so far as he was aware, there was no colliery in England employing the method at present, although there were a few on the Continent.

Mr. V. A. Wilkes (Brierley Hill) remarked that with regard to the reversal of the air-current, it would be within Mr. Charlton's recollection that some years ago he (Mr. Wilkes) had submitted a scheme for altering the fan on somewhat similar lines, and Mr. Charlton had thought rather favourably of it. Then he passed the scheme on to Mr. Johnstone, who did not give a very good opinion of it. But a somewhat similar arrangement had been adopted in Scotland, and that, he thought, had not been an unqualified success.

With regard to the reversal of the air by means of a second drift, without any alteration of the fan, that was, in his opinion, far and away the better plan. That was an idea which he was just adopting at his colliery; and he had provided a second drift, the reversal being affected by means of swinging doors. By that means the ventilation could be reversed in a few minutes, with practically no trouble at all. He thought that the second proposal in the paper was considerably in advance of any alteration in the fan or fan mechanism.

The Chairman said that frequent reference was made by writers in a manner that suggested that there was some vital

difference between blowing and exhausting fans, as regards efficiency. He thought that if any person would make a small calculation he would see at once that, whether a fan were put to blow or to exhaust, the efficiency need not be in any way affected. Mr. Charlton had put forward the suggestion that discussion should take place upon this point. Personally, he (the speaker) was unable to see that any discussion could possibly enlighten them on that subject. But whether a particular mine could be more successfully ventilated by blowing or by exhausting was entirely another question. The introduction of fans which permitted of the reversal of air was a very interesting and important subject at the present moment. The new Mines Act brought that subject forward, but he did not think that it was quite clear as to what the Act required. Whether it meant that the fan should be capable of reversing the whole of the air-current throughout the mine, or whether they had only to reverse the air in the shafts or the air in the main air-current, might be open to question. The intention, however, was perfectly clear, and that was that they should have an equipment capable of producing a reversal within such limits as might reasonably be required in the circumstances of each mine.

He would like to add his own thanks to Mr. Charlton for his excellent paper, which dealt with a subject of considerable interest and importance.

Mr. William Charlton (Walsall), in acknowledging the vote, said that he was extremely obliged to the members for the appreciation shown to his paper. Certain points might be answered at once, although he should prefer time and leisure to consider some of the others. He quite appreciated the remark made by Mr. Thacker, and indeed the idea was present in his own mind throughout the preparation of the paper, that a further enquiry was very much called for. When they considered that the report of the North of England and Midland Institutes dealing with mechanical ventilation was issued in 1899, that the tests were made a considerable number of years before that date, and that the enquiry was very limited in its scope, there seemed abundance of room for a complete inquiry into the subject of mechanical ventilation.

A point had been raised by Mr. Holland as to whether it was better to have a direct drive rather than a rope-drive. The point

made in his paper was that if a difference or change was made between the revolutions of the motor and those of the fan, then some form of gear was necessary. So far as his own observation was concerned, he was bound to say that a rope-drive seemed to have been most satisfactory.

With regard to the point raised by Mr. McTrusty, fans might be constructed showing a higher manometric efficiency than 100, and he had heard of one case in which the figure was given as 180. He had not the temerity and boldness necessary to make that statement, but the question of Murgue's investigations of the construction of blades might very profitably be revived and discussed.

With regard to the point raised as to what exactly was meant by reversal in the new Mines Act, he had laid a bait which he had hoped would draw forth some expression of opinion; he had deliberately dealt with the subject with that object, and regretted that so few had responded. Was it clear that the Act required only a simple reversal of the air—a reversal of direction between shaft and shaft? The Chairman had interpreted it to mean that reversal should be established so far as would reasonably be required. That appeared to cover the whole case, but, at the same time, did not carry them much further in the interpretation of the Act.

The further discussion of the paper was adjourned.

THE MANCHESTER GEOLOGICAL AND MINING SOCIETY.

SPECIAL MEETING,
HELD IN THE ROOMS OF THE SOCIETY, QUEEN'S CHAMBERS,
5, JOHN DALTON STREET, MANCHESTER,
MAY 14TH, 1912.

MR. GEORGE B. HARRISON, PRESIDENT, IN THE CHAIR.

ALTERATION OF RULES.

The HONORARY SECRETARY (Mr. Sydney A. Smith) read the circular dated April 2nd, 1912, which had been issued to the members in accordance with Rule XXXV., giving notice of the alteration in the rules to be proposed at this meeting, and stated that The Institution of Mining Engineers had on January 15th, 1908, altered its rules in order to meet the wish of the Society to admit geologists. The proposed change was to make certain rules as to the admission of members exactly the same as those of The Institution of Mining Engineers. The alteration was very slight, but it had been necessary to call this special meeting for the purpose.

The PRESIDENT (Mr. George B. Harrison) moved that Rule 1 be altered at Clauses *b*, *d*, and *e*, in accordance with the notice issued to the members, as follows:—

(*b*) Each Associate Member shall be a person connected with or interested in mining, metallurgy, engineering, or geology, and not practising as a mining, metallurgical, or mechanical engineer, or some other branch of engineering, or as a geologist.

(*d*) Associates shall be persons acting as underviewers, undermanagers, or in other subordinate positions in mines or metallurgical works, or employed in analogous positions in other branches of engineering.

(*e*) Students shall be persons who are qualifying themselves for the profession of mining, metallurgical, or mechanical engineering, or other branch of engineering, and such persons may continue students until they attain the age of twenty-five years.

Mr. WILLIAM PICKSTONE (Manchester) seconded the resolution, which was carried unanimously.

THE MANCHESTER GEOLOGICAL AND MINING SOCIETY.

GENERAL MEETING,

HELD IN THE ROOMS OF THE SOCIETY, QUEEN'S CHAMBERS,
5, JOHN DALTON STREET, MANCHESTER,
MAY 14TH, 1912.

MR. GEORGE B. HARRISON, PRESIDENT, IN THE CHAIR.

The following new members were elected, having been previously nominated:—

MEMBERS—

Mr. JAMES EVANS, Colliery Manager, 34, Tanybryn Street, Aberdare, Glamorgan.

Mr. JOHN HAROLD JACKSON, Mining Engineer, "San Remo," Grange Road, Urmston, Manchester.

Mr. GEOFFREY DIXON MAYHEW, Mining Engineer, Broughton Hall, Chester.

Mr. JOHN DRUMMOND PATON, Mechanical and Electrical Engineer, 25, Market Street, Manchester.

STUDENTS—

Mr. WILLIAM ALEXANDER, Mining Surveyor, 42, Park Road, Wigan.

Mr. ROY HOWIE, Mining Student, 1, Shed Street, Lower Ince, Wigan.

Mr. JOHN LOWE, Mining Student, Spring Vale, Eccleston Street, Wigan.

Mr. JOSEPH PETERS, Mining Student, 19, Smith Street, Skelmersdale, Ormskirk.

Mr. JAMES PLATT, Mining Student, Glenburn House, Skelmersdale, Ormskirk.

Mr. HUBERT SCHOLES, Mining Surveyor, 37, Church Street, Westhoughton, Bolton.

THE LATE MR. JOSEPH DICKINSON.

The PRESIDENT (Mr. George B. Harrison) said that since the last meeting the Society had suffered a serious and much lamented loss by the death of their revered member, Mr. Joseph Dickinson, and he had been asked by the Council to submit a resolution of condolence with his family. It was with no ordinary feelings that he did so, and everyone present would

doubtless regard the resolution with more intense feeling than they would a vote of condolence with the family of any other member of the Society. Mr. Dickinson, who was in his ninety-fourth year, was the oldest member of the Society, and up to the last had regularly attended the meetings. It was at their meeting on April 9th that he for the last time took part in their deliberations. Although Mr. Dickinson held strongly to his own opinion, he was always ready to give most courteous consideration to the views of those who might not agree with him.

Mr. Dickinson was born on November 24th, 1818, at Newcastle-upon-Tyne. His ancestors were connected with lead-mining in the Alston Moor district for several generations; his great grandfather was a mineral agent, and his grandfather was a mineral agent, who was succeeded by his eldest son, while Mr. Dickinson's father (a younger son) went to the estate offices at Newcastle-upon-Tyne. His maternal grandfather was also a mine-owner. Mr. Dickinson was a pupil of Mr. Thomas Sopwith, F.R.S., from 1833 to 1840, and conducted some classes in Sir Charles Lemon's Experimental Mining School, at the Royal Institution, Truro. In 1840, he entered the service of the owners of the Dowlais ironworks and mines, and by direction of Sir J. John Guest, the owner, he attended a course of practical analysis and assaying of iron-ores at what afterwards became the Royal School of Mines. In 1842, he was elected a Fellow of the Geological Society of London, and his name is one of the oldest on the roll of that illustrious Society. In the same year he set out the first railway-sidings at Bute Docks, Cardiff, for the Dowlais company. In 1847, he entered the service of the owners of Nithsdale ironworks, where he laid out the railways and opened out the mines. In 1850, he was appointed one of the first four Inspectors of Mines, and continued to act in this capacity until the beginning of 1892, when he retired on reaching the age of 73, still full of vigour and energy.

His numerous duties as Inspector of Mines and his special work on Committees and Royal Commissions were fully recorded, and there was no need to recite them. He (the President) therefore moved that the members of the Society should record their deep sympathy with the relatives of the late Mr. Joseph Dickinson.

Mr. William Pickstone (Kersal) seconded the resolution which had been moved in such fitting terms by the President.

Mr. Richard Sutcliffe (Horbury), who had known and had been intimately associated with Mr. Dickinson in mining operations in Ireland, desired to add his testimony to Mr. Dickinson's remarkable character. He had been in touch with their revered friend since 1872. He (the speaker) passed his examinations under him in 1874, and managed collieries in Ireland under him for upwards of 10 years. During all those years, and ever since, he never knew any miner to complain of the work of Mr. Joseph Dickinson. He never knew a colliery-owner or manager but looked upon him as a friend. In supporting the resolution, he (Mr. Sutcliffe) thought that it might be truly said of Mr. Dickinson that, while throughout his official life he never forgot that he was a Government Inspector of Mines, he always remembered that he was an English gentleman and the friend of every man.

Mr. John Ashworth (Manchester) said he would like to say a few words in support of the resolution, on account of the long friendship that had existed, not only between him and Mr. Dickinson, but also between that gentleman and his (the speaker's) father. He thought that the Society had been highly honoured by having so long connected with it a gentleman like Mr. Dickinson, who always showed kindness to every one of his fellow members.

The resolution was then passed in silence, everyone rising from his seat.

The following paper, entitled "Experiences on a Chinese Coal-field," was read by Mr. George S. Caldwell:—

EXPERIENCES ON A CHINESE COAL-FIELD.

By GEORGE S. CALDWELL.

Introduction.—Probably no more drastic change has overtaken any country in regard to political affairs, within a few weeks, than that which recently took place in the Celestial Empire. After centuries of despotic and somewhat patriarchal government, this has disappeared and given place, apparently by common consent, to a form of Republican Government. The change has been carried out with less bloodshed than would perhaps have been the case with what is commonly called a highly civilized nation. Under the new form of Government it is to be hoped that the best minds and intellects of the nation may be engaged to develop to the utmost extent the very great and varied natural resources of the country, and also that the racial mistrust which now exists may be replaced by a better understanding for mutual benefit.

Coal-fields of China.—(Fig. 1, Plate XI.). There are many coal-fields in China which are being worked at the present time by natives and foreigners. All the various kinds of coal are represented in one or other of the different districts. The Kaiping coal-field, near the coast, in the north-east, produces bituminous and semi-bituminous coal. The Lai Neu Ho coal-field, in the north of the province of Honan, produces nothing but anthracite. The Province of Shansi is nearly all one large coal-field, the estimated quantity of coal in this province alone being 630,000,000,000 tons., The Province of Hunan also contains extensive coal-fields.

The Lai Neu Ho coal-field, to which the writer calls special attention in this paper, lies to the north of the Ho Hang Ho, or Yellow River, about latitude 35° N. and longitude 114°E. This coal-field is worked by various native and European companies,

chiefly near the outcrop; but the coal has been proved for some distance to the south, which is nearly the direction of full dip. The inclination of the same amounts to about 1 in 5 (Fig. 2, Plate XI.).

Surface Configuration.—The surface forms one huge fertile plain to the south of Jai Mei Sen colliery. A little to the north of the colliery the land breaks up into a very rugged and mountainous district, which extends through the Province of Shansi. The Coal-Measures are thrown out at the foot of the first range of hills, called the Tai Hang Shan, and the Carboniferous Limestone in the second range. These hills, which extend east and west for a great distance, contain large deposits of iron-ore, which are being explored and worked, and will be eventually developed into a large iron-producing district.

Prospecting.—During recent years boring has been carried out in a thorough and systematic manner by Europeans under European management, and the coal-field has been proved for many square miles, with seams of coal varying from 10 to 40 feet in thickness. As the Sullivan type of boring machine was chiefly used, it was found advisable in cases where the soil or lœss was very thick to sink a well about 4 feet in diameter on to the hard strata and then to bore from this point, on account of the soil washing down and blocking the hole when water is used for drilling. This method also accelerated the prospecting.

The Chinese have a system of boring for water and other purposes with bamboo rods, which are split into narrow strips and act like the ordinary rope-boring appliances; this arrangement has been used to bore down to a depth of 500 feet.*

Sinking.—The operation of sinking is not so formidable as in Great Britain, as the strata is not very hard. Water is the only real obstacle, and this is encountered in considerable volume. There are about 200 feet thick of soil or lœss called Kwang To. This formation covers large tracts of land and is "wind-borne." There has been some controversy in the past as to its origin; but when one has experienced a few dust storms in

* See "Drilling with Bamboo Rods," by W. A. Moller, *Trans. Inst. M. E.*, 1908, vol. xxxvi., page 437.

Asia or Africa, little doubt as to the way in which the lœss has accumulated then remains: for during a dust storm the atmosphere is simply saturated with this extremely fine yellowish-brown dust, which after settling down becomes compact and appears to develop a kind of vertical cleavage. Where water-courses have cut their way through this formation, the sides stand perfectly vertical up to a height of 100 feet. In these banks are cut out many thousands of tenements for the cave-dwellers, and large numbers of the population near the mines are so housed.

During the sinking of shafts through the lœss, the sides stand for several yards without supports, thus enabling rapid progress to be made. Towards the bottom the soil contains a large proportion of land shells, and huge blocks of conglomerate, also containing shells. The water is found on top of the first layer of sandstone, being probably the stored-up rain-fall of many centuries, which, owing to the depth, can only find its way slowly to the rivers. The sandstone, which is about 100 feet thick, varies from an exceedingly fine to a very coarse texture, and appears to be in reality a conglomerate of quartz-pebbles with siliceous binding material.

The next formation consists of Coal-Measure shales somewhat similar to those found in England, the colour varying from a dark grey to a very dark green, until it merges into the black basses above the main coal-seam. This coal is a very hard smokeless anthracite, and varies from 16 to 20 feet in thickness. It makes an excellent steam-coal, and for household purposes burns very well in an open grate after being thoroughly ignited. It burns with a short non-luminous blue flame, producing a little reddish-brown ash. The coal on the face shows different degrees of texture and brightness. A band called You Ho May is exceedingly bright, with a mottled surface when broken. As the coal is very hard, it stands handling and transport exceedingly well. No inflammable gas has been found in the Main Coal Seam, but black-damp has been traced in the old workings. In rather large areas the coal exists in an amorphous state, resembling coarse graphite. The faces on the small faults or steps in these areas have quite a soapy feeling, and are very glossy.

Method of Working.—The method of working the coal-seam is an application of the "pillar-and-stall" system. Levels about

7 feet wide and 7 feet high are driven east and west from the pit in the lower portion of the seam, a very good and convenient parting being found 7 feet from the floor, and the remaining 11 feet of coal above forming an excellent roof. At a distance of 75 feet from the shaft, east-and-west rises and dips were driven at right-angles from the levels, at first 60, and later 100 feet apart. These were also cut 7 feet by 7, and the top coal stood for a long time with little or no timber.

Old workings and shafts (of which there were no indications on the surface) were unexpectedly cut into. These old workings are said by local tradition to have been abandoned about 200 years ago, the coal having been worked just round about the bottom of the old shafts until stopped by water and lack of ventilation.

Work was continued through these old workings until the soft or amorphous coal was found and proved for some distance by narrow headings and borings on the surface, and then abandoned, the pillars being brought back. All roads not required for haulage or ventilation were allowed to close up: this quickly took place, as the floor was rather soft and the "creep" came on rapidly. The method of getting the pillars was to take a ribbing in the bottom portion of the coal along one side of the pillar, and then let the "tops" fall by withdrawing the timber. Sometimes it was necessary to leave a thin barrier in the first ribbing in order to keep the fallen dirt from running into the road, and to recover the same when retreating, very little coal being lost by this method.

The fine coal is sold to the natives, who mix it with about an equal quantity of damp soil, and roll it between the hands into small balls about the size of walnuts, which are placed to dry in the sun. These small briquettes are used for household purposes in the cities, and burn very well in stoves built somewhat like miniature cupolas, which are placed in the centre of the room; and, as they are smokeless, they do not cause any serious inconvenience. These briquettes command a ready sale on account of the country being practically denuded of timber except for a few fruit-trees and cypresses, which latter are only planted in grave-yards, and are therefore held in great reverence.

Water Difficulties.—There are large volumes of water to deal with underground, which is only what might be expected in a

virgin area. The feeders of water found during the sinking operations were very erratic, and feeders alongside one another were proved to come from different sources. One small feeder was dammed back, and with a gauge registered a pressure of 60 pounds per square inch at a depth of 560 feet. This was within 40 feet of a large feeder which emptied itself freely into the shaft close by.

Another huge feeder, estimated at 70,000 gallons of water per hour, was tapped at a depth of 656 feet on the edge of an area of soft coal; but did not interfere with the flow of any previous feeders. This volume of water, however, became more than the pumps could deal with, and they were therefore abandoned, after an accident to the delivery-pipe. The water rose in the shafts up to 352 feet from the surface, and the pumps kept it at this level pending the arrival of a large Hathorn-Davy pump capable of dealing with 180,000 gallons per hour, with a 1,000-foot head. The total volume of water pumped was 216,000 gallons per hour from five different levels. The water had sometimes a slight smell of sulphuretted hydrogen, but no taste, and it was excellent for use in the boilers.

Ventilation.—That a system of ventilation was necessary was one of the most difficult matters to impress upon the Chinese mind. Separation-doors and brattice-cloths were erected under the instruction of a European, but when he was absent the door would be propped open or the brattice-cloth nailed on one side or torn down, because the workmen thought that they interfered with the drawing of coal or with shouting to one another. Often the missing brattice-cloths were converted into wearing apparel.

Shaft-Lining.—The shafts are lined and the insets walled with blocks of limestone quarried in the hills to the north, being worked on the surface to shape, marked, taken down the shaft, and erected to a marked template showing the position of each stone. All the blocks were about 2 feet long, 12 inches deep and 9 inches thick, and were designed to interlock with each other. These make an efficient and exceedingly fine lining, the Chinese masons being very clever in working the stone. The limestone boulders from the dry watercourses are burnt in circular kilns for lime, which is used for building purposes.

[illegible] [illegible] [illegible] [

a rope about an inch in diameter. These when wet are extremely elastic. A small number of the shafts are used for drawing coal in wicker baskets, the empty baskets being thrown back down the shaft to accelerate the ventilation, for which no special provision is made. The colliers go down for 2 or 3 days at a stretch, for the mere fact of winding workmen up and down the shaft each shift would seriously interfere with the output. No Coal Mines Regulation Acts exist, and winding is continued day and night, including Sunday, which is not a day of rest. Coal-mining is only suspended by some accident, or when the stock of coal on the surface has absorbed all the available capital.

Transport.—The mines accumulate large stocks of coal during the dry seasons, and await the flooding of the rivers to transport it down to the coast, a distance of 500 miles. In the shallow parts of the river the coal is unloaded, until the junks, which each carry about 30 tons, will float over. The coal is then re-loaded. The empty junks are hauled up stream by manual labour, as many as twenty men being engaged in spells, who take their turn of rest on the boat.

The Tao-Chin Railway passes within 2 miles of these native mines, and about 2,000 coolies are employed to convey the coal from the mines to the railway in wheelbarrows. Proposals were made to take the railway alongside the mines, but as this would interfere with the employment of barrow coolies, the matter was promptly dropped. A Chinese combination is a force to reckon with. Coal is taken for inland use a distance of about 40 miles by wheelbarrow with a donkey, or a sail if the wind be favourable, each barrow carrying a load of 700 catties, or nearly 1,000 pounds. The coolies travel on the foot-paths at the rate of about 3 miles per hour, and rest at the various hostels *en route.*

Labour.—There is a plentiful supply of cheap labour in the immediate vicinity of the mines, but the artisan class is chiefly recruited from the coast, many being reliable and skilful men who have gained their experience in shipping and manufacturing businesses on the coast. These men command a much higher rate of pay, on account of which they are treated by the natives with a certain amount of suspicion and dislike.

Coinage.—The coinage is a troublesome and expensive matter. The standard coin is the "cash piece," which varies from 1,200 to 1,400 to the tael; this again equals an ounce of silver, its present value being about 2s. 9d. No coins of this denomination are minted, the silver being used in its raw state. The workpeople are paid monthly by cheque on the native bank, which renders them an equivalent (minus a little commission) of the raw silver cut from an ingot by means of a large pair of shears.

Conclusion.—Although the writer has not made any attempt to contribute a highly scientific treatise, nor to propagate any new theory, he hopes that his paper will prove to be an interesting account of mining under exceptional difficulties of race and climate. The difficulties of race will quickly disappear when the large numbers of the present generation have completed their education on Western methods, and are able to appreciate the necessity of working hand in hand with foreign enterprise for the development of their rich country, as this will bring out the latent qualities which have been lying dormant for centuries, in administration, engineering, and all other branches of science which lead a country into the van of progressive nations, where the greatest good is spread over the greatest number.

The writer adds as an appendix some particulars of the wages paid to the various classes of workpeople, analyses of certain coals, and a section of the strata sunk through at the Jai Mei Sen Colliery.

APPENDIX.

TABLE I.—WAGES PAID TO WORKPEOPLE.

Workmen.	Datal Wage.		Hours Worked.	Interval for Meals.
	s. d.	s. d.		
Clerks	2 9	to 7 0	... 10 ...	2 hours.
Fitters	2 0	to 3 0	... 12 ...	do.
Smiths	2 0	to 2 6	... 12 ...	do.
Winders	2 0	to 2 6	... 8 ...	None.
Pumpers	0 9	to 2 0	... 8 ...	do.
Stokers	1 6	to 1 9	... 8 ...	do.
Carpenters	1 0	to 1 6	... 12 ...	2 hours.
Colliers	0 4	to 0 7	... 8 ...	None.
Coolies	0 3	to 0 5	... 12 ...	2 hours.

To illustrate Mr. George S. Caldwell's Paper entitled "Experiences on a Chinese Coal-field."

FIG. 1.—MAP OF THE COAL-FIELDS OF CHINA.

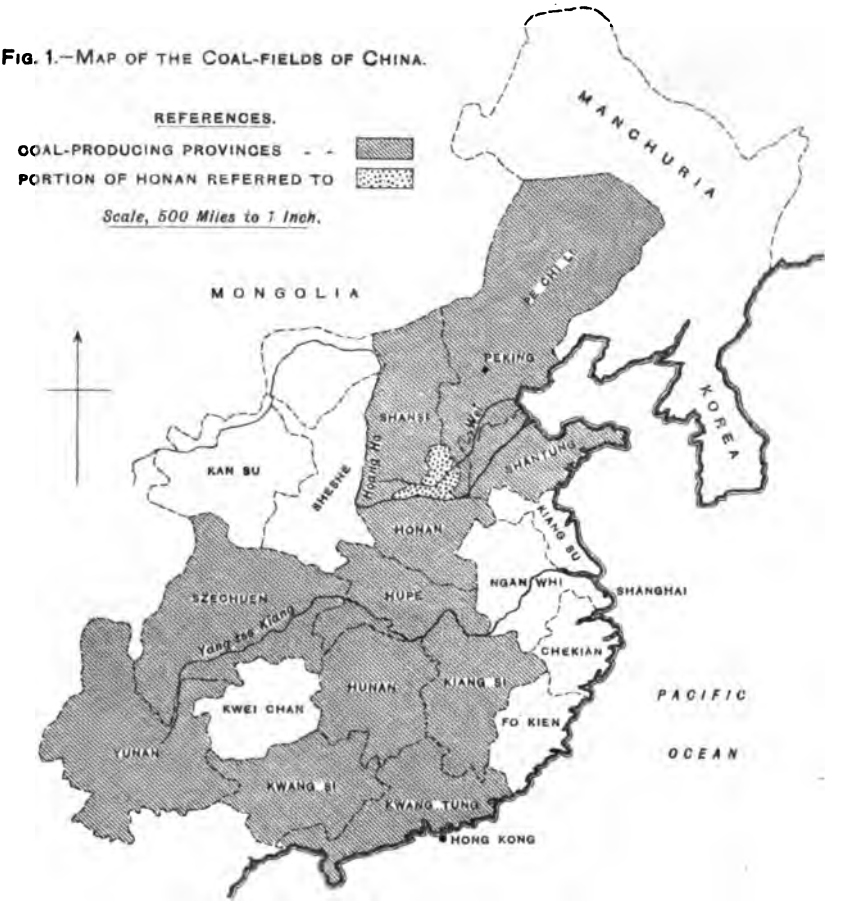


FIG. 2.—APPROXIMATE SECTION OF MINE.

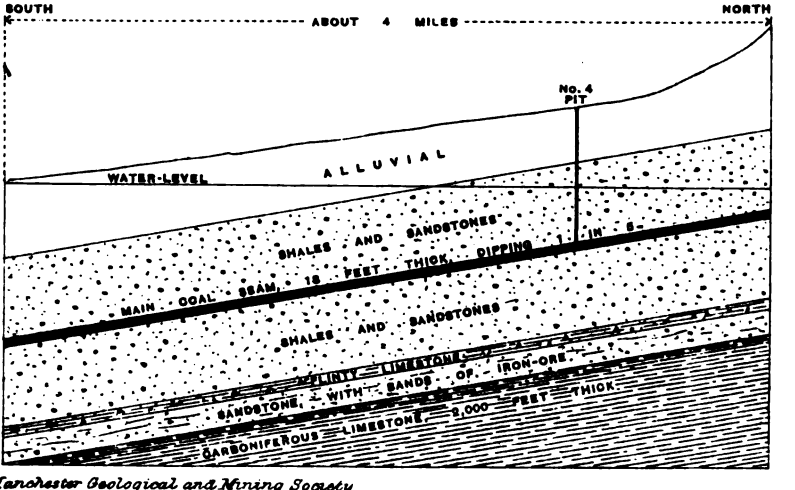


TABLE II.—AVERAGE COMPOSITION OF COAL FROM THE MAIN COAL SEAM, LAI NEU HO COAL-FIELD, HONAN, NORTH CHINA.

	Per cent.
Carbon	86·81
Sulphur	0·41
Ash	9·88
Moisture	2·90
Volatile matter	9·36
Total	109 36
Colour of ash	Whitish
Coke, per cent.	90·64
Calories	6,408
Evaporation at 212° Fahr., in pounds of water per pound of fuel	11·93

TABLE III.—COAL-MEASURE STRATA, PROVED BY SINKING AND BORING AT THE JAI MEI SEN COLLIERY, HONAN COAL-FIELD, NORTH CHINA (FIG. 2, PLATE XI.).

	Feet.
Alluvial.	
Red and yellow clays and conglomerates	250
Arenaceous clays and shales, yellow and brown sandstones	90
Coal-measures.	
Shales and sandstones	250
Main Coal Seam	18
Shales and sandstones	250
Flinty limestone	30
Brown and yellow sandstone, with bands of iron-ore	80
Carboniferous Limestone	2,000
Total depth from surface	2,968

Mr. RICHARD SUTCLIFFE (Horbury) said that he had much pleasure in moving a vote of thanks to Mr. Caldwell. Mr. Caldwell had dealt pretty fully with the different phases of the subject. Much of the coal in China, it seemed, like that in the South of Ireland, was anthracite. The Jarrow Seam of Ireland was the Upper Bed in the Lower Coal-Measures, and consequently the Middle Coal-Measures were all above the Jarrow Bed. It lay between the Mountain Limestone and the Middle Coal-Measures.

Mr. ALFRED J. TONGE (Hulton Collieries), in seconding the vote of thanks, said that Mr. Caldwell could have interested them much longer had he cared to do so, and one was sorry not to see on the table a few of the curios that he brought back with him on

his return home. He had noticed how interested some of them were to hear from Mr. Caldwell that there were no mining laws in China. That statement naturally rather appealed at the moment to colliery-owners and managers in this country. It was evident that the Chinese had some wonderful seams of coal. When a mining student, he had read of the thick seams of China, and wondered how long it would be before they were worked. Apparently, in Mr. Caldwell's opinion, the present generation was going to tackle the problem. Mr. Caldwell had spent some years in China, and doubtless he had given the meeting an accurate idea of the general mining conditions of that part of the world.

The resolution was carried unanimously.

Mr. James Lomax (Bolton) asked Mr. Caldwell whether he had seen any signs of fossil fish-remains or plants, either in the roof or in the floor of the coal-measures that he had described. It had been suggested that many of these coal-seams had been laid down in lagoons. If that idea was correct, there ought to be some evidence of fish-remains. Now, in the case of the Jarrow Seam of anthracite, as he understood it, in the floor of the seam there were found fossil remains of amphibians. In the coal about 8 or 10 inches from the floor there was a stratum of fish-remains; higher up the seam the fish-remains disappeared; whereas other layers of fish-remains appeared nearer the top, making altogether about three bands of fish-remains. At the top and in the roof there were other remains of plants and amphibians, showing that there had been a depression and an upheaval during the deposition of that particular seam of coal. He understood that the edge of this seam thinned out, as was often found in cannel seams also. If this were so, one could imagine that the vegetable matter was drift material, which had formed small islands that ultimately became water-logged, sank, and carried down anything in their way, such as fishes, etc., which would be imprisoned in the vegetable *débris*, and were now found as fossils. He wished to ask whether Mr. Caldwell had seen anything of that nature in the particular stratum of coal that he had been working. He understood that in some places anthracite, and in others what might be called bituminous coal, existed. It was strange that both these

forms of coal were found in the same area. How that arose he knew not. It was a question worthy of investigation. His own investigations had shown that gas was present and imprisoned in certain seams and bands of coal. They brought out also the fact that certain constituents in the coal, when let free, were detrimental to the working of the seam. He suggested that Mr. Caldwell should obtain some of the Chinese coal for microscopic examination, so that it could be compared with the British coals. He desired also to ask Mr. Caldwell whether he was sure that the Carboniferous Limestone was at the base of the seam.

Mr. G. W. Cooke (Manchester) said that in Mongolia there was a mine containing alternate seams of anthracite and bituminous coal in the following descending order:—(1) anthracite, (2) pure bituminous coal, (3) anthracite, and (4) bituminous coal. How these coals were formed, he was unable to say. He would like some members of more experience than himself to explain how anthracite and bituminous coal in alternate descending seams had been formed. In Manchuria, in a valley stretching for 30 miles, there was a mine containing lignite, which the Chinese were working. In Tientsin was the oldest worked mine in China. At first it was worked by the Chinese, but was now managed by Europeans. The Chinese bought their principal supply of coke from England and used it for smelting iron, because coke made from Chinese coal was inferior. The character of the Chinese miners depended on what part of the country they came from. In Tientsin, there were good miners working regularly. Miners had to be trained, and it was impossible to make a good miner out of an agricultural labourer in a short time. A question has been raised in regard to the limestone in China. There was the Mountain Limestone and the coal above it. In Tongking there were large quantities of coal with the limestone below.

Mr. George S. Caldwell (Westhoughton), after expressing his appreciation of the vote of thanks, said that the seam of which he had spoken was 18 feet thick, and was all one seam. The parting was only just a cleavage, and there was no material between. The coal was of different quality on each side of the cleavage, and varied in thickness. One quality, used for household pur-

poses, called Yo Ho May, was specially separated. It would not all make good house coal, but some of the bands would, and these were conspicuous by their brightness and mottled fracture. He could not say whether there were any river-beds in this seam. The area that was worked was very uniform in thickness, without any "wash-outs" or anything that resembled them. The whole of the area was practically free from faults. As to there being no mining laws in China, in his opinion the absence of such laws was not altogether an advantage. Probably, when the new Government got to work, mining laws would be introduced. There were plenty of fossils in the shales and in the black bass above the coal, but he had not found any fish-remains. It was true, however, that he had never made a very exhaustive search for them. If Mr. Lomax or the members thought that it would be of advantage to have such fossils and specimens, he could, no doubt, get some in the course of a few months. Probably they would be interesting to the Society. He did not know whether the bottom limestone was true Carboniferous or not, although it was so called. He had not heard of any disasters occurring through the burning of anthracite in China. There was certainly no provision made to carry away the products of combustion. A small quantity only was burnt for cooking, and it was too expensive for the natives to use for heating purposes. Concerning Mr. Cooke's remarks as to the native miners, there were no good miners as yet. A miner could not be made in 10 minutes. The men were very raw to commence with, and very careless; but probably, as years went on, they would make as good pitmen as they did workers in other spheres of life.

DISCUSSION OF MR. JAMES LOMAX'S PAPER ON "THE MICROSCOPICAL EXAMINATION OF COAL, AND ITS USE IN DETERMINING THE INFLAMMABLE CONSTITUENTS PRESENT THEREIN."*

Mr. James Lomax (Bolton) said that he had prepared some further specimens of coal under the microscope; but, as Mr. Garforth, the President of The Institution of Mining Engineers, would deliver his Presidential Address on June 6th, and as some

* *Trans. Inst. M. E.*, 1911, vol. xlii., pages 2, 459, 462, and 606; and 1912, vol. xliii., pages 88 and 249.

of those specimens would then be shown, he would not deal with them now. They would be put in a case, and go to the University at Leeds. In the meantime, he would like the members of the Society to go over to his laboratory and see the contents of the case. The specimens would show practically the origin of coal and its growth, from the plants right away to the coal; also the dust derived from the coal, the spores in it, and the resinous bodies generally, as found in the coal, would be shown.

The PRESIDENT (Mr. George B. Harrison) suggested that the Hon. Secretary should arrange for a visit of the members to Mr. Lomax's laboratory.

Mr. W. BOLTON SHAW (Manchester) said that Mr. Lomax had previously pointed out that embedded in the coal were little resinous bodies, the form of which was perfectly preserved. He believed that Mr. Lomax held that this rather confirmed his view that coal could not have been formed at a high temperature, as otherwise the form of these resinous bodies would have been destroyed. It might be possible to gain further information if a set of samples of coal were taken from a seam in which these bodies were largely present, and the samples subjected to different temperatures, say, between 100° and 400° Fahr., for a number of hours, and then slides prepared, from which it could be seen what the effect was on the resinous bodies. In this way it might be possible to fix the maximum temperature above which the coal could not have been formed. He did not know whether it would be possible to do this, or whether there were insuperable difficulties in the way.

Mr. LOMAX said, in answer to Mr. W. Bolton Shaw, that in mounting a piece of coal for slicing and for making a thin section, it was at once shown whether the coal gave off gas or not. For instance, let them take (1) an ordinary piece of bituminous coal, and (2) a piece of anthracite or Welsh steam-coal, and notice the action of each in mounting them. In the former case, if the coal contained alternating bands of resinous and non-resinous matter, it was extremely difficult to mount a section without gas or air-bubbles. Where the resinous matter was most prevalent, it seemed to swell, at the same time giving off innumerable tiny globules of gas: the other bands, which

were non-resinous, giving very little difficulty. Each specimen had, when pressed on the glass, to be heated to about 150° Fahr. in order to make it adhere to the mounting medium. After cooling, the medium became a solid layer between the glass slip and the specimen. Coals such as those mentioned above had to be treated sometimes for several days, in order to prevent the volatile matter and gas from escaping when the specimen was being mounted. Anthracite contained very little resinous matter, and did not cause much trouble. There might be imprisoned gas in cavities which was soon driven off at a low temperature, and its place taken up by the mounting medium. In many cases there could be seen the spaces or pseudomorphs of what may have been resinous bodies, similar to those in bituminous coals. In some anthracites there were some resinous bodies yet remaining.

With reference to the origin of the bituminous coals, there were a great many diverse opinions into which it was needless to enter. The microscopical examination of one particular seam had shown that the lower part of the seam contained numerous bands, consisting mostly of the resinous bodies which he had named *Ovalites* and *Amberites*. One part, 4 to 6 inches thick, consisted of nothing else. Ascending upwards in the seam there was a gradual diminution of these bodies, which were replaced chiefly by megaspores and microspores, until the upper portion of the seam consisted of laminations, the denser laminæ being composed of layers of megaspores alternating with lighter layers of microspores and other vegetable humus. All these had originated from organic matter, chiefly vegetable. It was what one would naturally expect from simple reasoning, combined with the evidence found in the adjoining shales, etc. The conditions under which a vegetable humus would accumulate in Carboniferous times would be similar to those of the present day. There would be as a beginning a lowly and diminutive order of plant life. Many of the plants would exist only for a short space, being replaced by others more vigorous, until ultimately the dominant types became those of the various genera and species of lycopods, such as *Sigillaria*, *Lepidodendron*, *Bothrodendron*, etc. Many of the plants existing during Carboniferous times gave off a great amount of resinous matter, as shown in the evidence supplied by sections

cut from petrifactions. These exhibited the structure of the tissues almost as perfectly as those of recent plants. If one looked at a piece of Trencherbone or Silkstone Hards, there would be found the alternating layers previously mentioned. These layers represented a single or a seasonal deposition of the reproductive organs of the gigantic lycopods of Carboniferous times. Many changes would occur in the slowly accumulating vegetable *débris*, bacterial and otherwise, until most of the delicate and tender plant-tissues would be obliterated, leaving little else but the most indestructible portions of plants, chiefly resinous bodies, in the shape of spores and other analogous substance.

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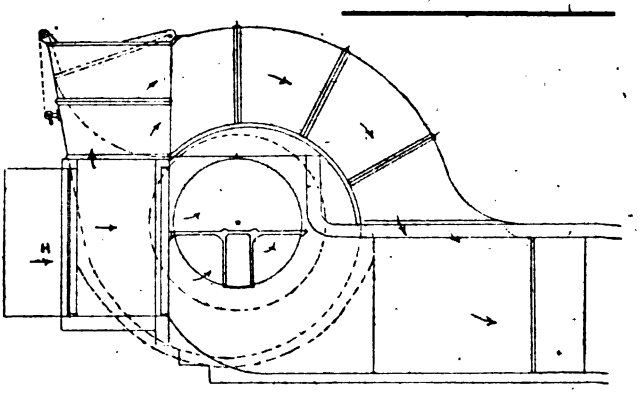

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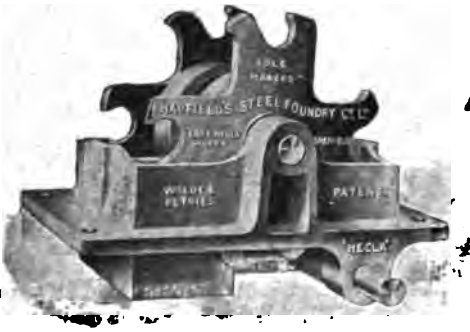

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Birmingham, September 11th, 12th, and 13th, 1912.

London, June 5th and 6th, 1913.

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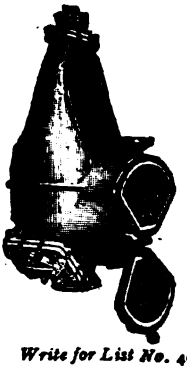

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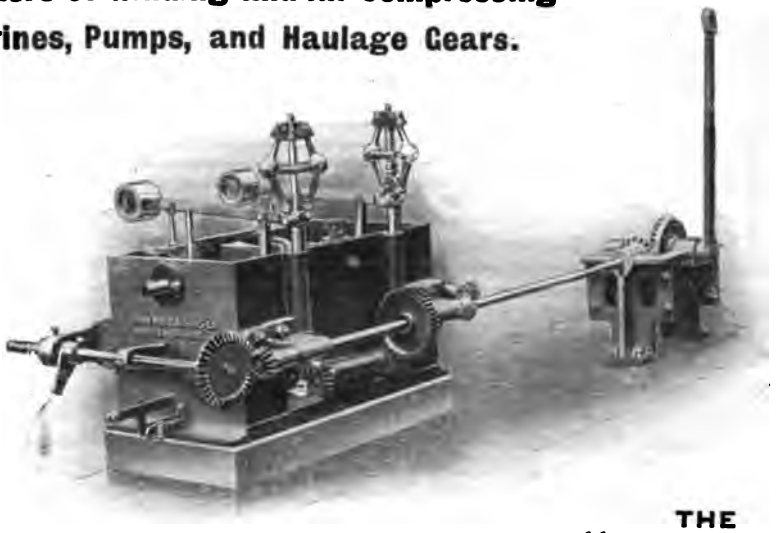

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It is estimated that the cost of the Window would be about £1,200; and, as it is probable that the number of subscribers would be large, it is thought that, generally, individual subscriptions need not exceed £2, or $10.

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The Council trust that the question of subscribing to the fund will receive the favourable consideration of the members of the Institution. All subscriptions should be sent to the Hon. Treasurer, Dr. J. H. T. Tudsbery, 12, Dartmouth Street, Westminster, S.W.; or to Messrs. Coutts & Company, Bankers, 440, Strand, London, W.C., the Treasurers of the Fund. [3

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INTERNATIONAL GEOLOGICAL CONGRESS,

TWELFTH SESSION, CANADA, 1913.

The International Geological Congress, on the joint invitation of the Government of Canada, the Provincial Governments, the Departments of Mines, and the Canadian Mining Institute, will hold its twelfth meeting in Canada during the summer of 1913.

For purposes of organization, a meeting of representatives from various scientific bodies of Canada was held in Toronto (Ontario) on December 2nd, 1910. Field-Marshal, His Royal Highness the Duke of Connaught, Governor-General of the Dominion of Canada, has graciously consented to become Honorary President. The President is Frank D. Adams, D.Sc., F.R.S., Dean of the Faculty of Applied Science and Logan Professor of Geology, McGill University, Montreal; and the General Secretary is R. W. Brock, M.A., F.R.S.C., Director of the Geological Survey of Canada, Ottawa. It is proposed to hold the meeting of the Congress in Toronto, beginning on or about August 21st. The Congress will continue in session for 8 days.

The following topics have been selected by the Executive Committee as the principal subjects for discussion:—(1) The coal-resources of the world; (2) differentiation in igneous magmas; (3) the influence of depth on the character of metalliferous deposits; (4) the origin and extent of the pre-Cambrian sedimentaries; (5) the sub-divisions, correlation, and terminology of the pre-Cambrian; (6) to what extent was the Ice Age broken by interglacial periods; and (7) the physical and faunal characteristics of the Palæozoic seas with reference to the value of the recurrence of seas in establishing geological systems.

A definite statement of the cost of each excursion will be issued later. Meanwhile the following generalizations may be of some practical value:—From Europe to Toronto, *via* Quebec or Montreal, the cost of a ticket for the single return journey will range between $125 and $350 (£25 and £70) according to the steamer selected and the accommodation desired. In the larger Canadian cities the charges at hotels for board and lodgings vary from $2.50 (10s.) per day and upwards, but less expensive accommodation is obtainable at boarding-houses in these cities, as well as at hotels in the smaller towns to be visited. For the ten days of the meeting in Toronto special accommodation will be provided at the University, at a cost of about $2 (8s.) per diem.

The Secretary will be pleased to answer all enquiries regarding the arrangements for the Congress. Correspondence should be addressed as follows:—The Secretary, International Geological Congress, Victoria Memorial Museum, Ottawa, Canada. Cable Address:—GEOCONG, OTTAWA. Messages may be sent in any of the following codes:—A. B. C. 5th; Lieber; Bedford McNeill, 1908.

A copy of the first circular issued by the Congress Authorities may be obtained, on application, from the Assistant Secretary, The Institution of Mining Engineers, Albany Buildings, 39, Victoria Street, Westminster, S.W. [3

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BYE-LAW 9.—The Ordinary Members, Associate Members, and Honorary Members, Associates, and Students shall have notice of, and the privilege of attending, the ordinary and annual general meetings, and shall receive all publications of the Institution. They may also have access to, and take part in, the general meetings of any of the Federated Institutes.

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THE CORRELATION OF OUR COAL-FIELDS.

During the last few years great progress has been made in the Correlation of the Coal-fields of England and Wales, and of the individual coal-seams throughout each district. The need of this investigation must have been felt very frequently, and at times acutely, by every mining engineer; its importance therefore needs no further emphasis. For the purpose of this research, the fossil mollusca (that is, "the mussel-bands" and "fossil shells" of the practical miner) have proved of the greatest service. In the hands of a few workers the results are steadily accumulating, but not so rapidly as might be if the number of collectors were increased. It is with the object, therefore, of accelerating this work that the assistance of colliery managers, under-managers, and students in every coal-field is earnestly invited.

In collecting, the following points should be observed:—(1) The shells to be obtained *in situ*; (2) the shells to be numbered or marked distinctively; (3) the locality, pit, or colliery to be given (not necessarily for publication); and (4) the position of the shell-bed with respect to some known coal-seam.

It is desired that the specimens, accompanied by the above information, should be sent to Mr. J. T. Stobbs, Dunelm, Basford Park, Stoke-upon-Trent, who will be glad to return them after being named, if requested; postage expenses will also be repaid in special circumstances.

As the results are published from time to time in the *Transactions*, all assistance received in response to this appeal will be properly acknowledged.

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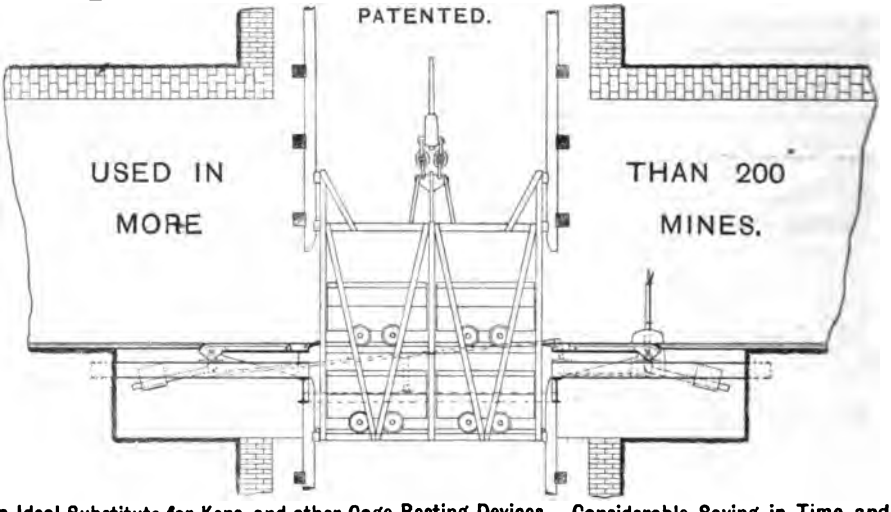

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ADDRESSES WANTED.

—Notices and *Transactions* addressed to the following members at the addresses given have been returned by the Post Office. Any information as to the present addresses of any of these gentlemen, in order that communications may be forwarded, will be welcomed by the Assistant Secretary. In order to obviate such occurrences, members are requested to notify the Secretary of their own Institute, as well as of The Institution of Mining Engineers, immediately of any change of address.

Mr. Andrew Aird, late of 2, Low Motherwell, Motherwell.

Mr. George Anderson, late of Newstead, 29, Kenwood Park Road, Sheffield.

Mr. William F. Anderson, late of 4, South Gray Street, Edinburgh.

Mr. William Armstrong, late of 44, Main Street, Carronshore, Falkirk.

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Mr. Thomas M. Greenshields, late of Banksimulla Colliery, Charanpur P.O., *via* Asansol, E.I.R., Bengal, India.

Mr. Scott Gunn, late of 23, Thornhill Park, Sunderland.

Mr. Thomas Hamilton, late of 38, Bath Street, Glasgow.

Mr. Henry Richard Hancock, late of Holwell, Whitchurch, Tavistock.

Mr. Carlos A. Lynes Hoskold, late First Engineer, Inspector of the National Department of Mines and Geology, Calle Charcas, 1222, Buenos Ayres, Argentine Republic, South America.

Mr. Algernon Tinsley James, late of Old Blackwell, Alfreton.

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The Sixth Congress of the International Association will be held at New York and Washington commencing on September 3rd, 1912, under the auspices of the American Society for Testing Materials. Prof. H. M. Howe, President of the Association, will act as President of the Congress, and Prof. E. Marburg, of Philadelphia, as Secretary. The Congress will be divided into Sections A - Metals; B—Concrete, Cement, Stone; and C—Miscellaneous.

Members desirous of taking part in the Congress are requested to notify their intention as soon as possible to the representative of the Association for Great Britain, Mr. G. C. Lloyd, Secretary of the Iron and Steel Institute, 28, Victoria Street, Westminster, London, S.W. [12

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Members may purchase copies of the Transactions of the following Corresponding Societies at the rates named below plus 2s. to cover expense of remittances, postage, etc. :—

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The proprietors of the *Colliery Guardian* have agreed to allow Students and Associates of The Institution of Mining Engineers to obtain the *Colliery Guardian* at the following special reduced rates, payable in advance :—United Kingdom, twelve months, 10s. 6d.; six months, 5s. 6d.; and three months, 3s 0d.; Foreign and Colonial, twelve months, 17s. 0d.; six months, 8s. 9d.; and three months, 4s. 8d. Applications for a copy of the special order form should be made to the Assistant Secretary, The Institution of Mining Engineers, Albany Buildings, 39, Victoria Street, Westminster, London, S.W.

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Transactions of The North of England Institute of Mining and Mechanical Engineers.

Anyone having copies of Vols. III. and IV. (or portions thereof) for sale, will oblige by sending particulars, with price, to the Assistant Secretary, The Institution of Mining Engineers, Albany Buildings, 39, Victoria Street, Westminster, London, S.W.

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The advertisements of the firms mentioned under each heading can be found by referring to the List of Advertisers on page xv.

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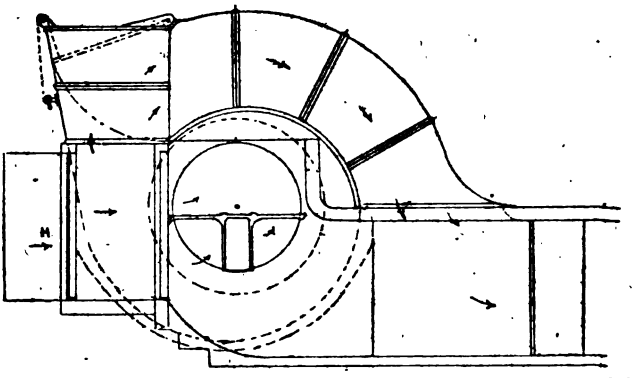

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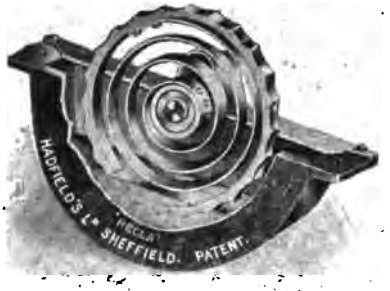

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GENERAL MEETINGS, 1913:—
London, June 5th and 6th.
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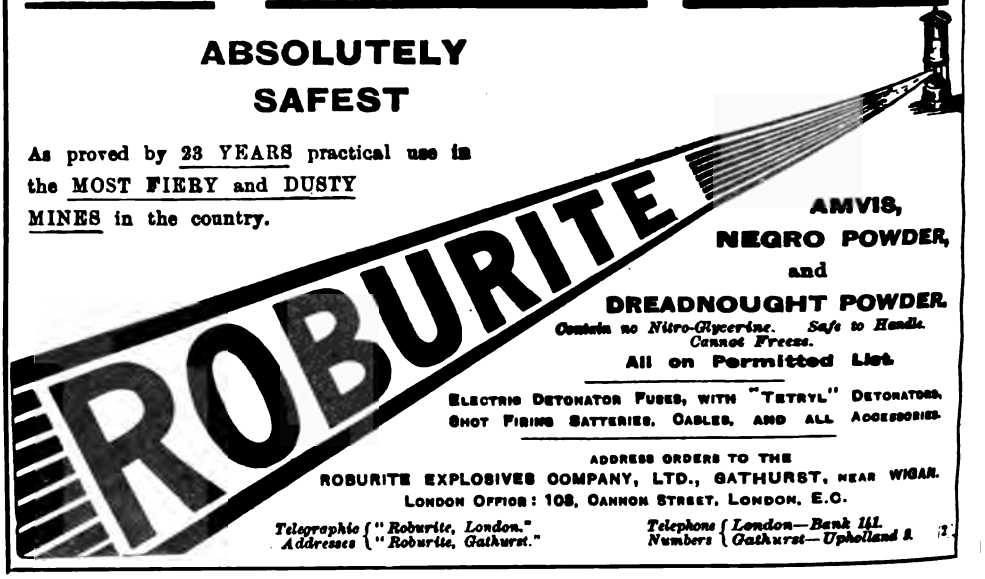

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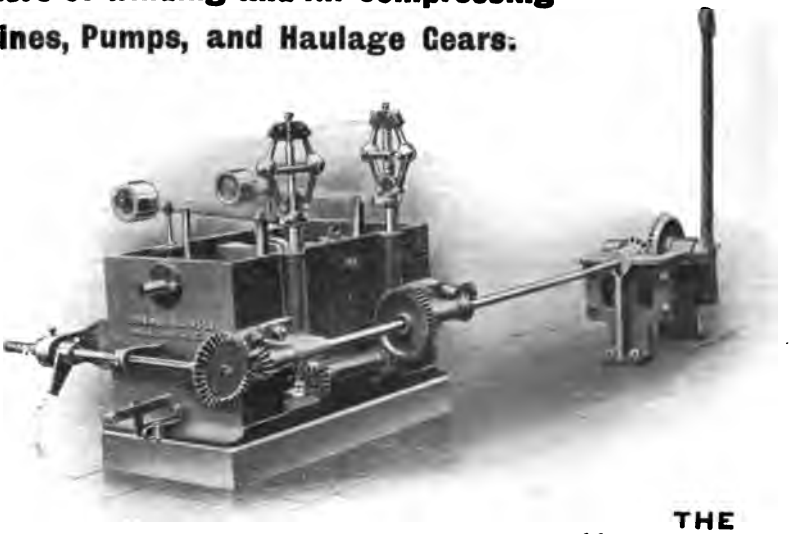

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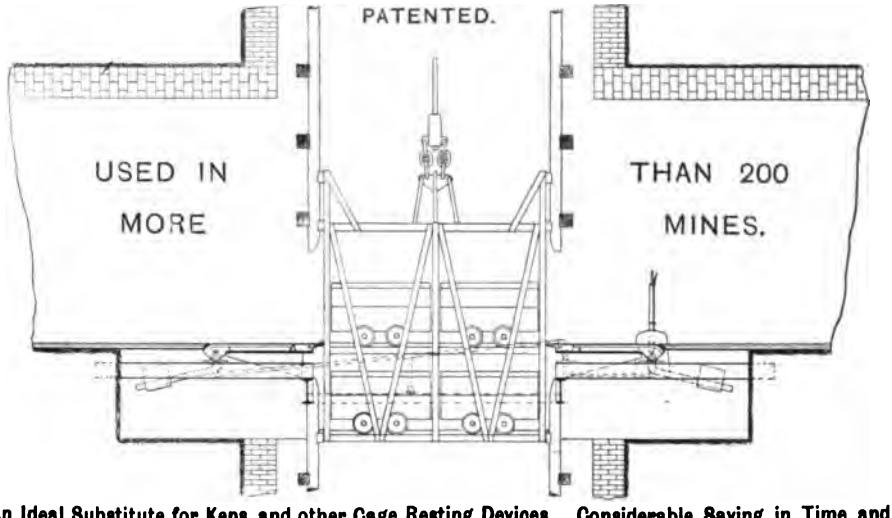

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The International Geological Congress, on the joint invitation of the Government of Canada, the Provincial Governments, the Departments of Mines, and the Canadian Mining Institute, will hold its twelfth meeting in Canada during the summer of 1913.

For purposes of organization, a meeting of representatives from various scientific bodies of Canada was held in Toronto (Ontario) on December 2nd, 1910. Field-Marshal, His Royal Highness the Duke of Connaught, Governor-General of the Dominion of Canada, has graciously consented to become Honorary President. The President is Frank D. Adams, D.Sc., F.R.S., Dean of the Faculty of Applied Science and Logan Professor of Geology, McGill University, Montreal; and the General Secretary is R. W. Brock, M.A., F.R.S.C., Director of the Geological Survey of Canada, Ottawa. It is proposed to hold the meeting of the Congress in Toronto, beginning on or about August 21st. The Congress will continue in session for 8 days.

The following topics have been selected by the Executive Committee as the principal subjects for discussion:—(1) The coal-resources of the world; (2) differentiation in igneous magmas; (3) the influence of depth on the character of metalliferous deposits; (4) the origin and extent of the pre-Cambrian sedimentaries; (5) the sub-divisions, correlation, and terminology of the pre-Cambrian; (6) to what extent was the Ice Age broken by interglacial periods; and (7) the physical and faunal characteristics of the Palæozoic seas with reference to the value of the recurrence of seas in establishing geological systems.

A definite statement of the cost of each excursion will be issued later. Meanwhile the following generalizations may be of some practical value:—From Europe to Toronto, *via* Quebec or Montreal, the cost of a ticket for the single return journey will range between $125 and $350 (£25 and £70) according to the steamer selected and the accommodation desired. In the larger Canadian cities the charges at hotels for board and lodgings vary from $2.50 (10s.) per day and upwards, but less expensive accommodation is obtainable at boarding-houses in these cities, as well as at hotels in the smaller towns to be visited. For the ten days of the meeting in Toronto special accommodation will be provided at the University, at a cost of about $2 (8s.) per diem.

The Secretary will be pleased to answer all enquiries regarding the arrangements for the Congress. Correspondence should be addressed as follows:—The Secretary, International Geological Congress, Victoria Memorial Museum, Ottawa, Canada. Cable Address:—GEOCONG, OTTAWA. Messages may be sent in any of the following codes:—A. B. C. 5th; Lieber; Bedford McNeill, 1908.

A copy of the first circular issued by the Congress Authorities may be obtained, on application, from the Assistant Secretary, The Institution of Mining Engineers, Albany Buildings, 39, Victoria Street, Westminster, S.W. [4

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Quarries and methods of quarrying.
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Rock-drills.
Safety-lamps.
Screening, sorting, and cleaning of coal.
Shipping and discharge of coal-cargoes.
Sinking, coffering, and tubbing of shafts.
Spontaneous ignition of coal and coal-seams.
Steam-condensation arrangements.
Steam-power plants.
Submarine coal-mining.
Subsidences caused by mining operations.
Surface-arrangements at mines.
Surveying and surveying instruments.
Transport on roads.
Tunnelling methods and appliances.
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Watering coal-dust.
Water-incrustations in boilers, pumps, etc.
Winding-arrangements at mines.
Winning and working of mines at great depths.

For selected papers, the Council may award prizes. In the conferment of awards, no distinction is made between communications received from members of the Institution and those received from others.

BYE-LAW 9.—The Ordinary Members, Associate Members, and Honorary Members, Associates, and Students shall have notice of, and the privilege of attending, the ordinary and annual general meetings, and shall receive all publications of the Institution. They may also have access to, and take part in, the general meetings of any of the Federated Institutes.

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THE CORRELATION OF OUR COAL-FIELDS.

During the last few years great progress has been made in the Correlation of the Coal-fields of England and Wales, and of the individual coal-seams throughout each district. The need of this investigation must have been felt very frequently, and at times acutely, by every mining engineer; its importance therefore needs no further emphasis. For the purpose of this research, the fossil mollusca (that is, "the mussel-bands" and "fossil shells" of the practical miner) have proved of the greatest service. In the hands of a few workers the results are steadily accumulating, but not so rapidly as might be if the number of collectors were increased. It is with the object, therefore, of accelerating this work that the assistance of colliery managers, under-managers, and students in every coal-field is earnestly invited.

In collecting, the following points should be observed:—(1) The shells to be obtained *in situ*; (2) the shells to be numbered or marked distinctively; (3) the locality, pit, or colliery to be given (not necessarily for publication); and (4) the position of the shell-bed with respect to some known coal-seam.

It is desired that the specimens, accompanied by the above information, should be sent to Mr. J. T. Stobbs, Dunelm, Basford Park, Stoke-upon-Trent, who will be glad to return them after being named, if requested; postage expenses will also be repaid in special circumstances.

As the results are published from time to time in the *Transactions*, all assistance received in response to this appeal will be properly acknowledged.

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The Institution of Mining Engineers.

KELVIN MEMORIAL.

The Engineering Societies of the British Empire and of the United States of America have had under consideration the erection in Westminster Abbey of a Memorial Window to the late Lord Kelvin, as a distinguished Engineer long associated with the profession in the Advancement of Science, and its application to enterprises of world-wide importance. They have ascertained that the Dean and Chapter would welcome the addition of such a window to those erected in the North Aisle as memorials of eminent Engineers, of which that to Sir Benjamin Baker was the latest.

It is estimated that the cost of the Window would be about £1,200 ; and, as it is probable that the number of subscribers would be large, it is thought that, generally, individual subscriptions need not exceed £2, or $10.

The Institution of Mining Engineers is represented on the Kelvin Memorial Committee by the President (Dr. W. E. Garforth), the Chairman of the Finance Committee (Mr. H. C. Peake), the Honorary Secretary (Prof. L. T. O'Shea), and Mr. R. A. S. Redmayne, C.B., H.M. Chief Inspector of Mines.

The Council trust that the question of subscribing to the fund will receive the favourable consideration of the members of the Institution. All subscriptions should be sent to the Hon. Treasurer, Dr. J. H. T. Tudsbery, 12, Dartmouth Street, Westminster, S.W. ; or to Messrs. Coutts & Company, Bankers, 440, Strand, London, W.C., the Treasurers of the Fund. [4

CHANGE OF ADDRESS.—It is particularly requested that members should advise the Parcel-post Department, as well as the Letter Office, of any temporary change of address. Unless this is done, parcel-post packets will not be re-addressed, but will be returned to the offices of the Institution, London, thus incurring further expense for postage.

ADDRESSES WANTED.

—Notices and *Transactions* addressed to the following members at the addresses given have been returned by the Post Office. Any information as to the present addresses of any of these gentlemen, in order that communications may be forwarded, will be welcomed by the Assistant Secretary. In order to obviate such occurrences, members are requested to notify the Secretary of their own Institute, as well as of The Institution of Mining Engineers, immediately of any change of address.

Mr. Andrew Aird, late of 2, Low Motherwell, Motherwell.

Mr. George Anderson, late of Newstead, 29, Kenwood Park Road, Sheffield.

Mr. William Armstrong, late of 44, Main Street, Carronshore, Falkirk.

Mr. Samuel Baillie, late of Parkfield Colliery, Pucklechurch, Bristol.

Mr. Alexander Richard Bekenn, late of Dundee Coal Company, Limited, Talana, Natal, South Africa.

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Mr. Scott Gunn, late of 23, Thornhill Park, Sunderland.

Mr. Thomas Hamilton, late of 38, Bath Street, Glasgow.

Mr. Henry Richard Hancock, late of Holwell, Whitchurch, Tavistock.

Mr. Carlos A. Lynes Hoskold, late First Engineer, Inspector of the National Department of Mines and Geology, Calle Charcas, 1222, Buenos Ayres, Argentine Republic, South America.

Mr. Algernon Tinsley James, late of Old Blackwell, Alfreton.

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Mr. Samuel Matthew Robins, late of 28, Harefield Road, Brockley, London, S.E.

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The Canadian Mining Institute, New Series, Volumes VII. to XIII., 10s. 6d. per volume, post free.
The Mining Society of Nova Scotia, Volumes IV. to XVI., 1s. 3d. per volume, post free.

Members by forwarding a cheque for £3 6s. 9d. to the Assistant Secretary of The Institution of Mining Engineers (Mr. PERCY STRZELECKI, 39, Victoria Street, Westminster, London, S.W.), may obtain a set of the above-mentioned volumes; or by forwarding a cheque for £1 1s. 3d., a copy of the latest volume of each of the above-named Societies.

The proprietors of the *Colliery Guardian* have agreed to allow Students and Associates of The Institution of Mining Engineers to obtain the *Colliery Guardian* at the following special reduced rates, payable in advance:—United Kingdom, twelve months, 10s. 6d.; six months, 5s. 6d.; and three months, 3s 0d.; Foreign and Colonial, twelve months, 17s. 0d.; six months, 8s. 9d.; and three months, 4s. 8d. Applications for a copy of the special order form should be made to the Assistant Secretary, The Institution of Mining Engineers, Albany Buildings, 39, Victoria Street, Westminster, London, S.W.

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Transactions of The North of England Institute of Mining and Mechanical Engineers.

Anyone having copies of Vols. III. and IV. (or portions thereof) for sale, will oblige by sending particulars, with price, to the Assistant Secretary, The Institution of Mining Engineers, Albany Buildings, 39, Victoria Street, Westminster, London, S.W.

INDEX OF ENGINEERING SPECIALITIES.

The advertisements of the firms mentioned under each heading can be found by referring to the List of Advertisers on page xv.

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Mavor & Coulson, Ltd., Glasgow.

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Hadfield's Steel Foundry Co., Ltd., Hecla Works, Sheffield.

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THE INSTITUTION OF MINING ENGINEERS.

Formation of a Library.

Steps having been taken for the formation of an adequate Library for the Institution, the Council have pleasure in stating that gifts have been received from several members and others.

The Council will be pleased to receive books on mining, etc., or sets of *Proceedings* of any of the engineering societies, for placing in the Library, as the want of suitable works of reference is greatly felt in connexion with the editing of the *Transactions*. The Library is specially in need of the following publications:—

Annual Reports of H.M. Inspectors of Mines: District No. 8, 1898; District No. 12, 1900 and 1904.
British Association for the Advancement of Science: *Annual Reports* for 1884, 1885, and 1886.
Colliery Guardian, Vols. XXXIV., LXXXVII., LXXXIX., XCIII., and XCVII.
Geological Society of London: *Quarterly Journal*, Vols. I., II., and III.
Geologists' Association: *Proceedings*, Vols. I. to VIII., XIII., and XV.
Institution of Civil Engineers: *Proceedings*, Vols. I. to XX. inclusive.
Institution of Mechanical Engineers: *Proceedings*, 1862 to 1867 inclusive.
Iron and Steel Institute: *Transactions*, Vol. I. (1869-1870); *Journal*, 1871-1874 inclusive; 1881, Vol. II.; 1882, Vol. II.; and from 1901 to 1909 inclusive.
Mines and Quarries: General Report and Statistics, 1898, Part 3; and 1899, Part 3.
North of England Institute of Mining and Mechanical Engineers: *Transactions*, Vols. III. and IV.
South Wales Institute of Engineers: *Proceedings*, Vol. IX., No. 1, Part 2.
Yorkshire Geological and Polytechnic Society, *Proceedings*, Vols. I. to V.
Reports of Royal Commissions on Mines.

All communications respecting the above should be addressed to the Assistant Secretary, The Institution of Mining Engineers, Albany Buildings, 39, Victoria St., Westminster, London, S.W. [26

THE INSTITUTION OF MINING ENGINEERS.

NOTICE TO AUTHORS.

Writers of Papers are requested to send in all Drawings, Diagrams, or other Illustrations, in a state suitable for direct photographic reproduction. Such illustrations should be drawn on a large scale, in Indian ink, and with lettering adapted to a reduction in scale. Where illustrations are numerous, much time would be saved if Authors would indicate in advance those considered essential to the understanding of their papers.

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The Assistant Secretary, Albany Buildings, 39, Victoria Street, Westminster, S.W., will be pleased to give advice to Authors as to the preparation of their illustrations.

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With reference to the entry of the publications of this Institution into the United States of America free of duty, the Collector of Customs at the port of New York was interviewed by the late Mr. R. P. ROTHWELL, acting on behalf of the Institution, with the result that the Appraiser at that port decided that publications similar to the Transactions, etc., of this Institution, are entitled to free entry into the United States according to paragraph 501 N.T.; but as it will be impossible for him to keep a special watch upon any such matter that duty may be imposed upon, he recommends that in case duty be charged, a protest should be made by the individual member calling attention to this paragraph.

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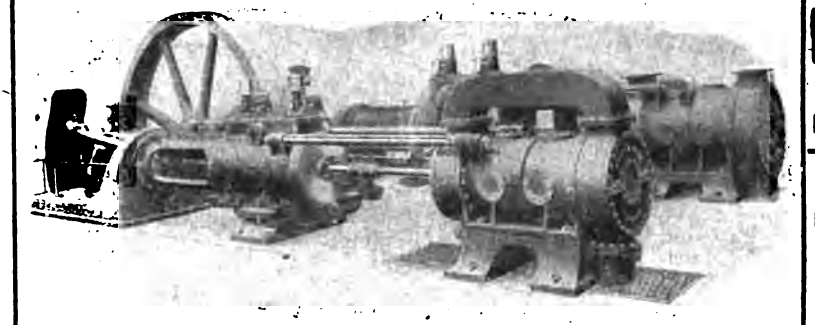

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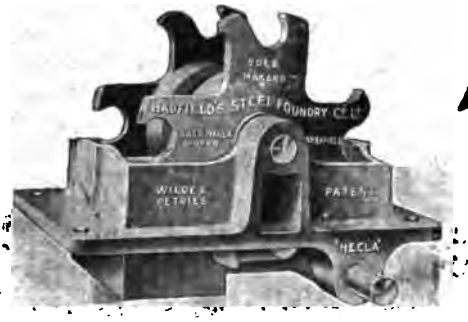

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Manchester, September 24th, 25th, and 26th.

Pages i to lxxvi; and 607 to 632.

See page xi for detailed Contents of Part.

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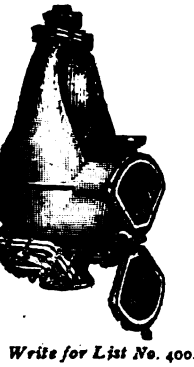

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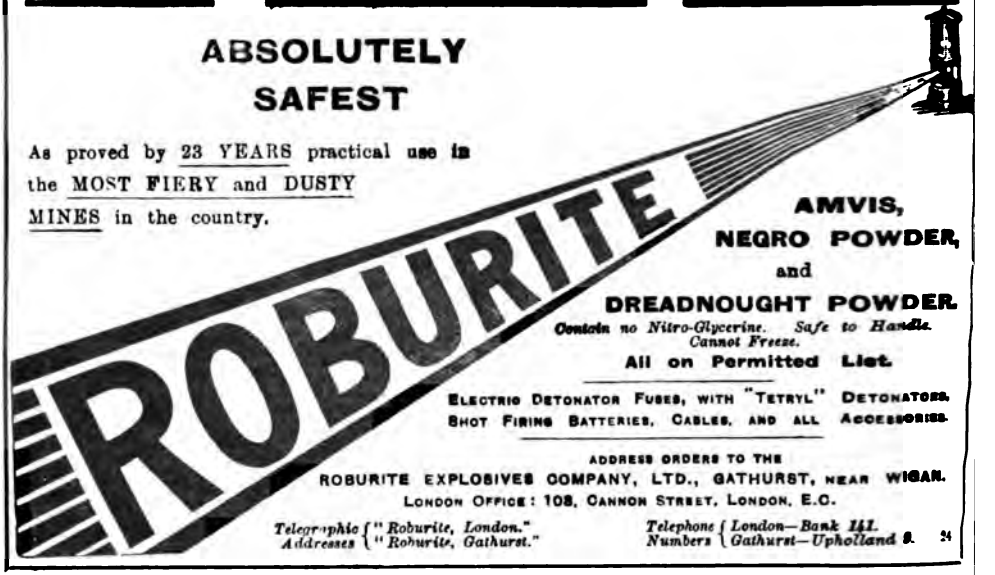

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It is estimated that the cost of the Window would be about £1,200; and, as it is probable that the number of subscribers would be large, it is thought that, generally, individual subscriptions need not exceed £2, or $10.

The Institution of Mining Engineers is represented on the Kelvin Memorial Committee by the President (Dr. W. E. Garforth), the Chairman of the Finance Committee (Mr. H. C. Peake), the Honorary Secretary (Prof. L. T. O'Shea), and Mr. R. A. S. Redmayne, C.B., H.M. Chief Inspector of Mines.

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INTERNATIONAL GEOLOGICAL CONGRESS,
TWELFTH SESSION, CANADA, 1913.

The International Geological Congress, on the joint invitation of the Government of Canada, the Provincial Governments, the Departments of Mines, and the Canadian Mining Institute, will hold its twelfth meeting in Canada during the summer of 1913.

For purposes of organization, a meeting of representatives from various scientific bodies of Canada was held in Toronto (Ontario) on December 2nd, *1910*. Field-Marshal, His Royal Highness the Duke of Connaught, Governor-General of the Dominion of Canada, has graciously consented to become Honorary President. The President is Frank D. Adams, D.Sc., F.R.S., Dean of the Faculty of Applied Science and Logan Professor of Geology, McGill University, Montreal; and the General Secretary is R. W. Brock, M.A., F.R.S.C., Director of the Geological Survey of Canada, Ottawa. It is proposed to hold the meeting of the Congress in Toronto, beginning on or about August 21st. The Congress will continue in session for 8 days.

The following topics have been selected by the Executive Committee as the principal subjects for discussion:—(1) The coal-resources of the world; (2) differentiation in igneous magmas; (3) the influence of depth on the character of metalliferous deposits; (4) the origin and extent of the pre-Cambrian sedimentaries; (5) the sub-divisions, correlation, and terminology of the pre-Cambrian; (6) to what extent was the Ice Age broken by interglacial periods; and (7) the physical and faunal characteristics of the Palæozoic seas with reference to the value of the recurrence of seas in establishing geological systems.

A definite statement of the cost of each excursion will be issued later. Meanwhile the following generalizations may be of some practical value:—From Europe to Toronto, *via* Quebec or Montreal, the cost of a ticket for the single return journey will range between $125 and $350 (£25 and £70) according to the steamer selected and the accommodation desired. In the larger Canadian cities the charges at hotels for board and lodgings vary from $2.50 (10s.) per day and upwards, but less expensive accommodation is obtainable at boarding-houses in these cities, as well as at hotels in the smaller towns to be visited. For the ten days of the meeting in Toronto special accommodation will be provided at the University, at a cost of about $2 (8s.) per diem.

The Secretary will be pleased to answer all enquiries regarding the arrangements for the Congress. Correspondence should be addressed as follows:—The Secretary, International Geological Congress, Victoria Memorial Museum, Ottawa, Canada. Cable Address:—GEOCONG, OTTAWA. Messages may be sent in any of the following codes:—A. B. C. 5th; Lieber; Bedford McNeill, 1908.

A copy of the first circular issued by the Congress Authorities may be obtained, on application, from the Assistant Secretary, The Institution of Mining Engineers, Albany Buildings, 39, Victoria Street, Westminster, S.W. 16

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The Council will be pleased to receive books on mining, etc., or sets of *Proceedings* of any of the engineering societies, for placing in the Library, as the want of suitable works of reference is greatly felt in connexion with the editing of the *Transactions*. The Library is specially in need of the following publications:—

American Institute of Mining Engineers: *Transactions*, Vols. II. to XVI., and from Vol. XXXVII. onwards.
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Mines and Quarries: General Report and Statistics, 1899, Part 3.
North of England Institute of Mining and Mechanical Engineers: *Trans.*, Vols. III. and IV.
South Wales Institute of Engineers: *Proceedings*, Vol. IX., No. 1, Part 2.
Yorkshire Geological and Polytechnic Society, *Proceedings*, Vols. I. to V.
Reports of Royal Commissions on Mines.

All communications respecting the above should be addressed to the Assistant Secretary, The Institution of Mining Engineers, Albany Buildings, 39, Victoria St., Westminster, London, S.W. [2

THE INSTITUTION OF MINING ENGINEERS.

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Writers of Papers are requested to send in all Drawings, Diagrams, or other Illustrations, in a state suitable for direct photographic reproduction. Such illustrations should be drawn on a large scale, in Indian ink, and with lettering adapted to a reduction in scale. Where illustrations are numerous, much time would be saved if Authors would indicate in advance those considered essential to the understanding of their papers.

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LETTING OF COUNCIL CHAMBER.—The Council of The Institution of Mining Engineers are prepared to let their Council Chamber for private arbitrations, etc. (meetings of public companies excepted). The Chamber is about 36 feet long by 23 feet wide, and is furnished with long Board Table, Chairs, etc. Terms on application to the Assistant Secretary, Albany Buildings, 39, Victoria Street, Westminster, London, S.W. [2

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With reference to the entry of the publications of this Institution into the United States of America free of duty, the Collector of Customs at the port of New York was interviewed by the late Mr. R. P. ROTHWELL, acting on behalf of the Institution, with the result that the Appraiser at that port decided that publications similar to the Transactions, etc., of this Institution, are entitled to free entry into the United States according to paragraph 501 N.T.; but as it will be impossible for him to keep a special watch upon any such matter that duty may be imposed upon, he recommends that in case duty be charged, a protest should be made by the individual member calling attention to this paragraph.

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THE CORRELATION OF OUR COAL-FIELDS.

During the last few years great progress has been made in the Correlation of the Coal-fields of England and Wales, and of the individual coal-seams throughout each district. The need of this investigation must have been felt very frequently, and at times acutely, by every mining engineer; its importance therefore needs no further emphasis. For the purpose of this research, the fossil mollusca (that is, "the mussel-bands" and "fossil shells" of the practical miner) have proved of the greatest service. In the hands of a few workers the results are steadily accumulating, but not so rapidly as might be if the number of collectors were increased. It is with the object, therefore, of accelerating this work that the assistance of colliery managers, under-managers, and students in every coal-field is earnestly invited.

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The advertisements of the firms mentioned under each heading can be found by referring to the List of Advertisers on page xv.

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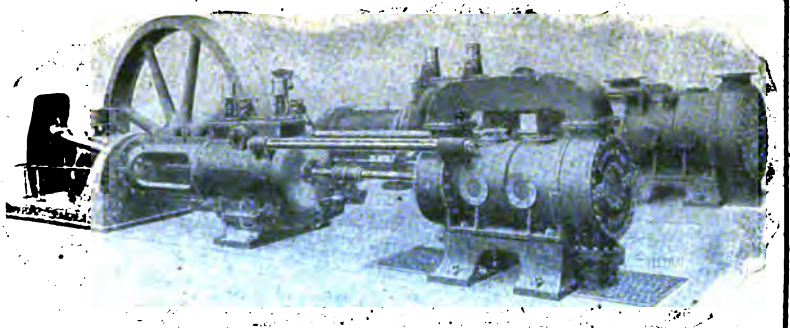

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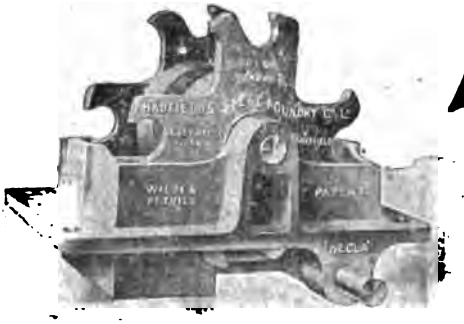

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